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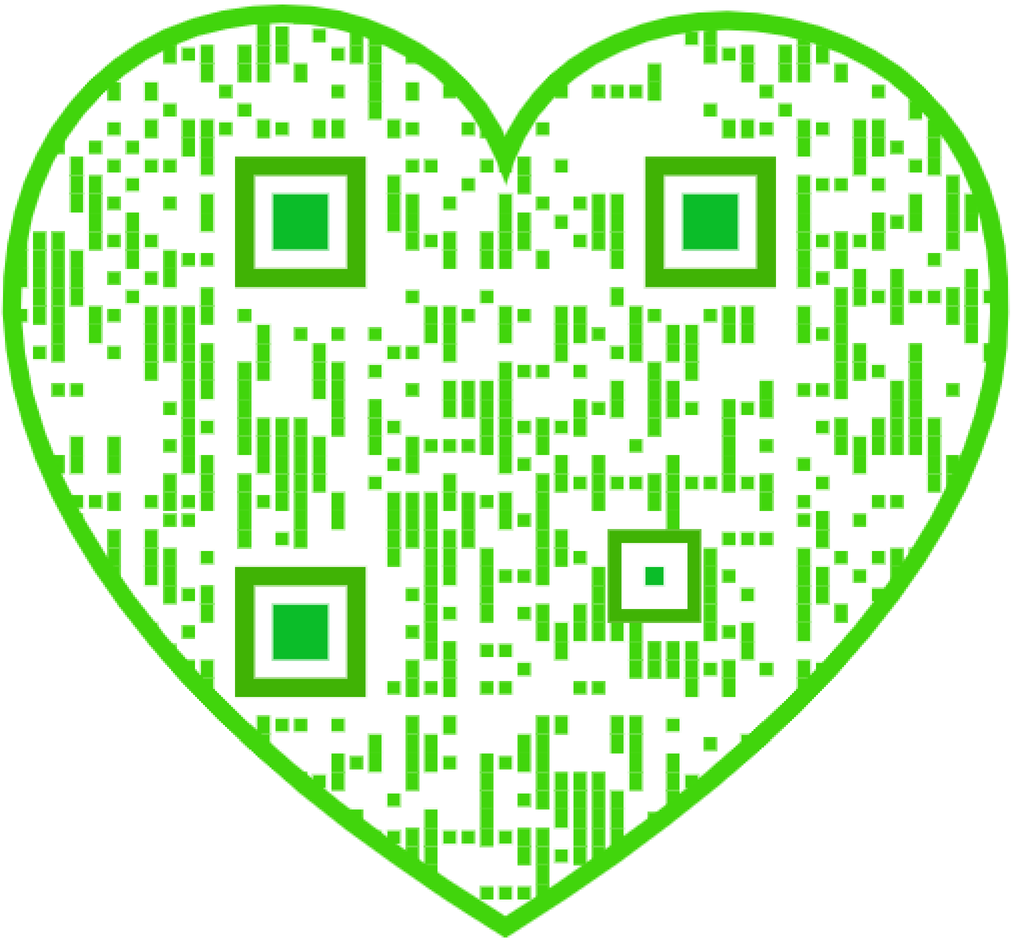
Psychology
Why elite athletes practise mental flexibility

Egyptology
The skeletons that could rewrite our history of the Pyramids

Smoking
Clearing the air around the health risks of vaping



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FROM THE EDITOR

I've always wanted to visit Silfra in Iceland. I can't really explain why, other than by simply stating what it is.

Iceland sits upon two continental plates – the Eurasian plate and the North American plate. These are huge chunks of Earth's surface – slabs of the planet's top layer of crust – which are yawning apart at a pace of 2cm (just shy of 1in) every year. This movement creates fissures in Earth's surface, like cracks in its shell.

In Iceland, the Silfra fissure happens to sit over an aquifer, a spot where glacial meltwater gathers underground, and so this crack became a lake. Here then, is the only body of water in the world that you can dive into and find yourself swimming between two tectonic plates. You can, almost, reach out and touch the Eurasian plate with one hand and the North American plate with the other.

I couldn't tell you why that appeals to me as an idea, as something to see before I die, but it does. While the fissure is around 60m (200ft) deep underwater, in my imagination, swimming through those waters would feel like Earth was opening up beneath me.

Why am I talking about Silfra? It's because the idea that there's another world beneath us has a special kind of hold on humanity, one that's almost as alluring as the idea that there's life beyond Earth. If you disagree, just count how many bad movie remakes there have been of Jules Verne's classic novel, *Journey to the Centre of the Earth*.

The thing is, seismology is now in a place where it's able to give us a detailed picture of what's really going on deep inside the planet. And every time it does, our understanding of what it's like down there changes. Head to p60 to find out what we've discovered.

Daniel Bennett

Daniel Bennett, Editor

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Behold the natural wonders of the Americas, from the Amazon to the Great White North. This 10-part epic, narrated by Tom Hanks, explores the dramatic landmass, from top to toe.
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CrowdScience: Are there global food allergy hotspots?
Dr Alex Lathbridge investigates why rates of food allergies are climbing worldwide, and why they appear to be more prevalent in the west than in the east.
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The Climate Question: How do you stop a megacity from going underwater?
Bangkok, a 'megacity' of more than 10 million people, is sinking. Reporter Jordan Dunbar travels to Thailand to uncover what plans are in place to keep both rising tides and rivers at bay.
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What's the world's oldest cheese? →p83

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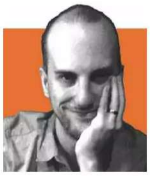

COLIN STUART
What can giant mountains, hidden deep beneath our feet, reveal about Earth's past, present and future? Astronomy author Colin investigates. →p60

KELLY OAKES
Adopting a flexible mindset could make achieving your life goals easier. Science writer Kelly discovers how, and asks why some psychologists recommend you retrain your brain. →p46

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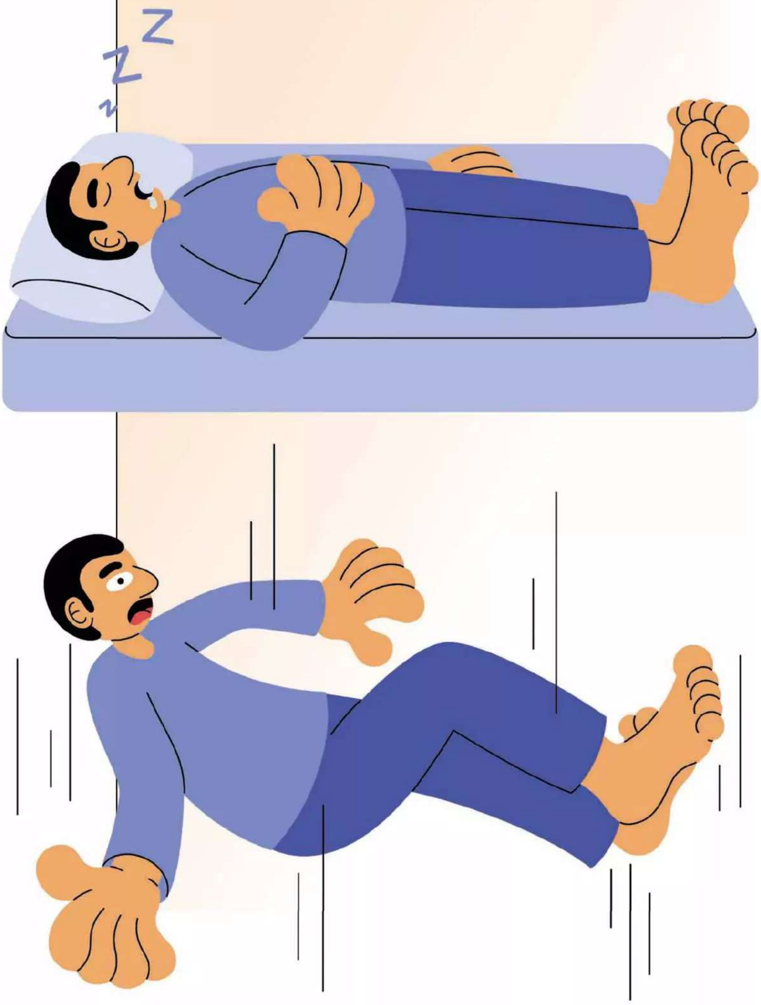

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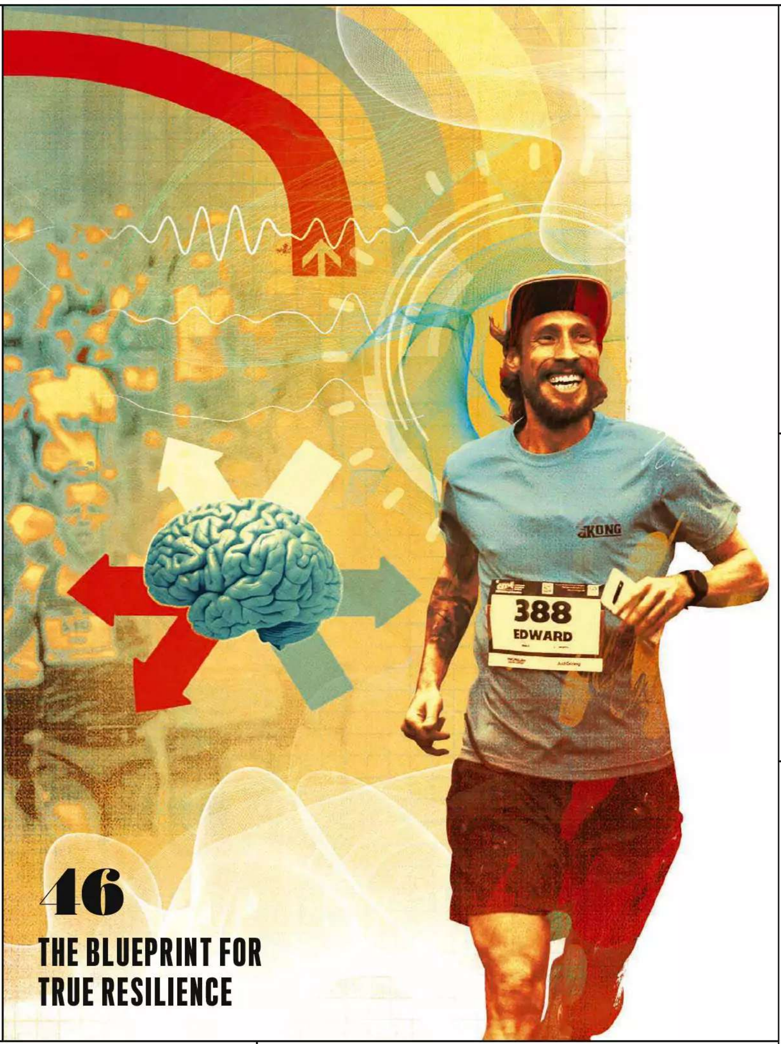

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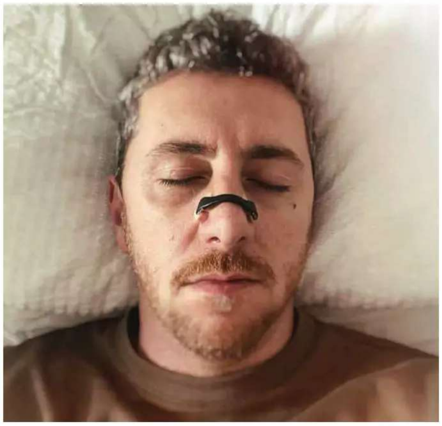

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SOFIA QUAGLIA

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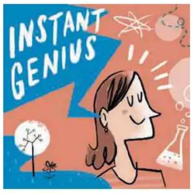

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EYE OPENER

The colours of home

As hard as it might be to believe, this is the place we call home. Earth is the green ball glowing eerily on the right, and the galaxy where it – and the rest of the Solar System – resides, the Milky Way, is the swirling mass emerging from behind. This awe-inspiring image was captured by NASA astronaut Donald Pettit on 29 January 2025, during his stay on the International Space Station (ISS).

The ISS orbits 425km (265 miles) above Earth's surface and was passing over the Pacific Ocean off the coast of Chile when Pettit reached for his camera. It was just before sunrise, hence the white glow on the horizon. The green you can see is the abundant phytoplankton in the ocean being illuminated by the rising Sun.

Look closer, however, and you'll notice the faint purple haze in Earth's atmosphere. This is an effect known as airglow and it's happening all the time, all around the planet. Airglow appears 50–300km (approx 30–180 miles) above the planet's surface, but is easiest to see from above, especially when contrasted against the blackness of space.

It's caused by molecules (mostly nitrogen and oxygen) being energised by ultraviolet radiation from the Sun. Atoms in the lower atmosphere release that excess energy by bumping into one another. But the upper atmosphere is much thinner, so atoms are less likely to collide. Instead, they release their energy by emitting photons – the smallest particles of light – and producing this purple haze.

NASA/DON PETTIT

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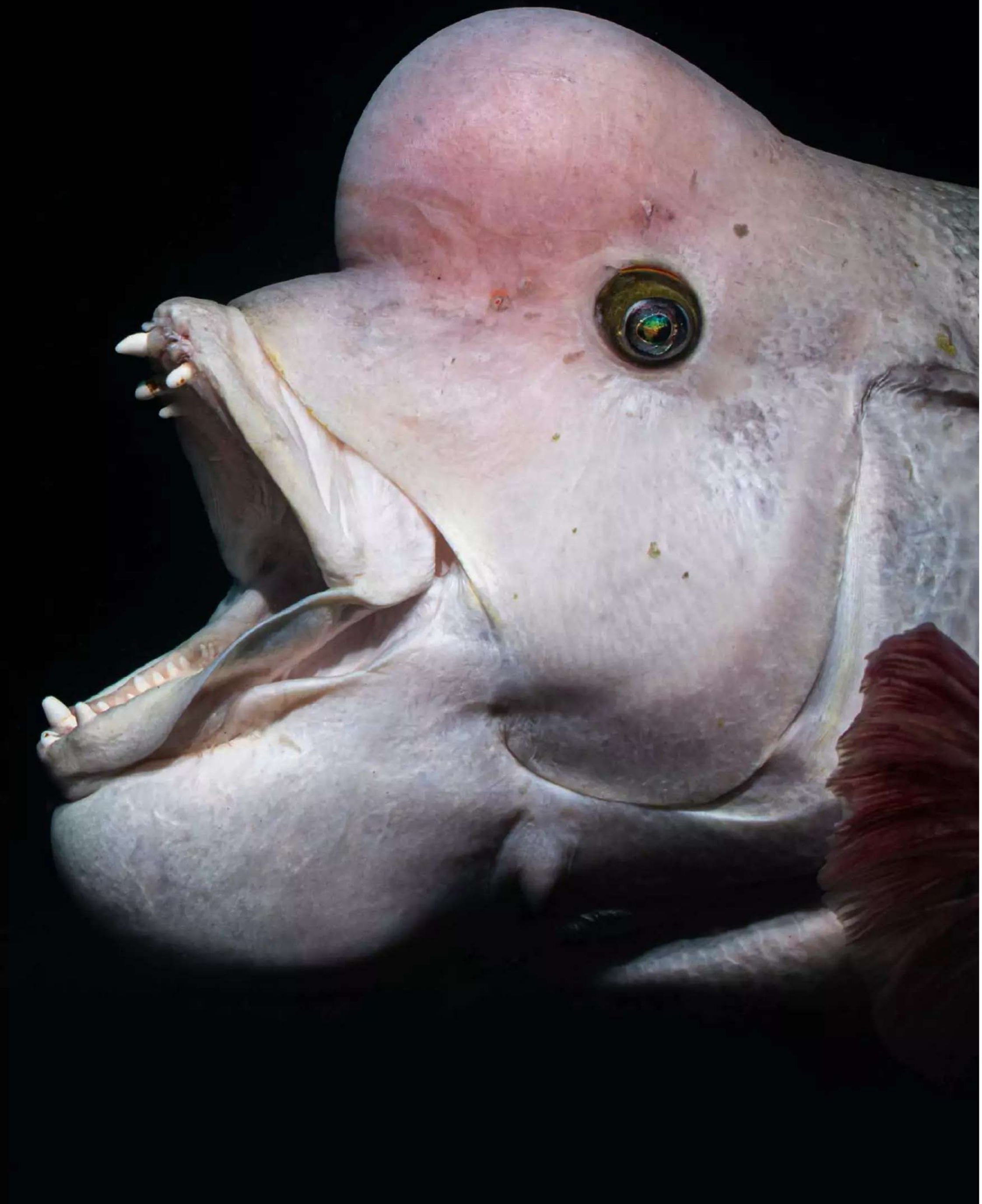
Screaming in the darkness

NIIGATA, **JAPAN**



This award-winning picture captures two Asian sheepshead wrasse (*Bodianus reticulatus*) fighting to establish dominance. The young challenger (on the right) is facing off against the older fish in a bid to claim his territory and become the sole male to breed with the females in it.

Male Asian sheepshead wrasse are big fish. They can reach up to 1m (3ft) in length and 13kg (30lbs) in weight. As in other wrasse species, dominance is established through a 'big mouth contest'. The rivals approach each other with their mouths agape, as if they're bellowing into each other's faces. Then they turn away, 'return to their corners' and do it again. This process is repeated until one fish backs down.

Typical male behaviour, you might think. But it might surprise you to learn that both of these fish began their lives as females. All Asian sheepshead wrasse start out as female, but at around 10 years old, whichever one is biggest usually transitions over a period of months to become a male.

Once the switch is complete, the new fish emerges – bigger than before, with a newly white body and an even more bulbous forehead – to take on the existing dominant male.

EDUARDO ACEVEDO/UPY 2025

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EYE OPENER

Mach diamonds

PALMDALE, **CALIFORNIA**

This is the loud end of the X-59, a 'quiet' supersonic aircraft being developed by NASA and Lockheed Martin. Planes have been breaking the sound barrier since 1947, but the thunderous sonic booms they create mean supersonic flight is only permitted over the ocean. That's something the scientists and engineers building this plane hope to change.

But before the X-59 can take to the skies to see if its 'boom-muffling' design works, its engine must be tested to make sure it can generate sufficient thrust to reach supersonic speeds. That's what you see happening here. But what you can also see, are the Mach diamonds the jet is producing in the process.

Mach diamonds form in a jet's exhaust plume when it hits air of higher pressure.

Due to the way hot exhaust gases expand as they exit a jet engine, they're actually at a lower pressure than the surrounding air. The air's greater pressure pinches the exhaust gases in, creating the front tip of the diamond. But this pinching effect increases the pressure of exhaust gases behind the tip so much that they reach a point where they're hot enough to reignite. The reignition causes the gases to overexpand so they're once again below the pressure of the surrounding air, and are pinched back to form the rear of the diamond.

859
NASA
X-59
N859NA

LOCKHEED MARTIN/GARY TICE

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FEEDBACK

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LETTER OF THE MONTH

Double glazing will help reduce the amount of heat escaping from your home

Don't forget the windows

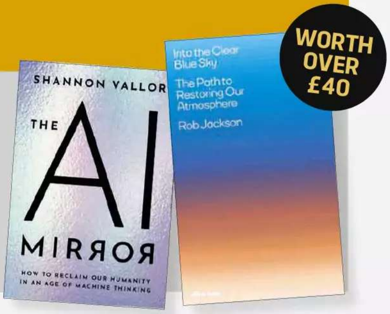
I was very surprised that the 'Build a better home' feature (January, p60) didn't include a section on glazing. Heat loss through windows can account for a significant slice of the running costs of a house. A single pane of glass can lose around 30 times more heat than a wall in a modern, well-insulated house.

Considering how much of the overall surface area of a typical house is glazed, I think it's well worth upgrading your windows before installing a heat pump.

Eddie Green, Lancashire

WRITE IN!

The writer of next issue's Letter of the Month will receive a pair of hardback popular science books: **The AI Mirror** *by Shannon Vallor, and* **Into the Clear Blue Sky** *by Robert B Jackson.*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THE AI MIRROR
HOW TO RECLAIM OUR HUMANITY IN AN AGE OF MACHINE THINKING
Into the Clear Blue Sky
The Path to Restoring Our Atmosphere
Rob Jackson
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Irritable bowel syndrome manifests in the gut, but that's not always where experts look for the cause

Mind vs body

Regarding Andy Ridgway's feature on irritable bowel syndrome (IBS) – 'Hard to stomach' (February, p52) – while it's true that anxiety and day-to-day life pressures can cause a spike in IBS symptoms, the transition to an illness state is more likely to be caused by a combination of long-term stressors.

In the absence of positive diagnostic medical test results, many IBS patients have been told by doctors that their condition is 'in their minds', suggesting that worry and anxiety are the only causes. It would be more accurate to say that the illness is in the body. Once the stress factors behind IBS are identified and addressed, a return to full health is possible.

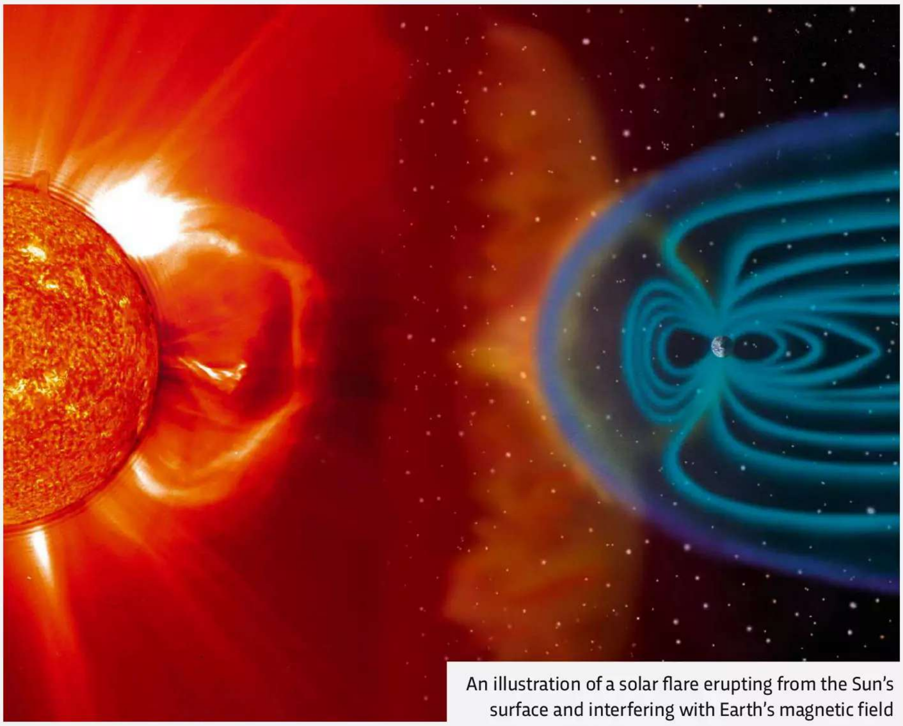
Alex Zeytounian, Bexleyheath

A problem for planes?

The news story about a study on the frequency of solar superflares in your January issue ("'Extreme' solar radiation storm could hit Earth", p21) got me thinking. The latest airliners are "fly by wire", meaning that flight controls are handled electronically, rather than mechanically.

If there was a superflare as strong as the Carrington event of 1859, would it knock out

> **“JUST BECAUSE THE RESEARCH WAS PUBLISHED, DOESN’T MEAN ITS SCIENTIFIC PURSUIT IS OVER. SCIENCE IS A METHOD NOT A FINISHED PRODUCT”**
>
> SOFIA QUAGLIA, p30



An illustration of a solar flare erupting from the Sun’s surface and interfering with Earth’s magnetic field

the electronics in modern aircraft and leave them unable to land safely?

Barry Cash, Bristol

Dr Robert Watson, a senior lecturer in the Department of Electronic & Electrical Engineering at the University of Bath, who wasn’t involved with the study, replies…
The 2008 Qantas Airways accident was attributed to the sort of effect you might get from high-energy solar particles causing problems with a flight computer. [Qantas Flight 72, flying from Singapore to Perth, suddenly made two unexpected dives without the pilots’ input. A number of passengers and crew were injured and the flight had to make an emergency landing in Western Australia.]

Having multiple back-up, or ‘redundant’ sensors that kick into action if the main sensors fail, should help to stop most potential electronic problems. If one sensor is affected by a rogue charged particle and goes haywire, the redundant sensors can ‘outvote’ the incorrect one, keeping the plane on course. But this is still vulnerable to human error – it’s suspected that in the Qantas accident, the crew had the redundant sensors switched off.

But a Carrington-type event would be orders of magnitude worse in terms of numbers and the energy of particles.

While you can use shielding to protect some things, my understanding is that this offers a ‘knife-edge’ margin of error. If the shielding is too thin, it’s ineffective. If it’s too thick, the high-energy particles it stops or slows down can produce their own kind of dangerous secondary radiation, known in particle physics as ‘Bremsstrahlung’.

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ANNUAL SUBSCRIPTION RATES (INC P&P):
UK/BFPO £83.86; Europe & Eire €114;
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Audit Bureau of Circulations 347,189 (combined, Jan-Dec 2024)

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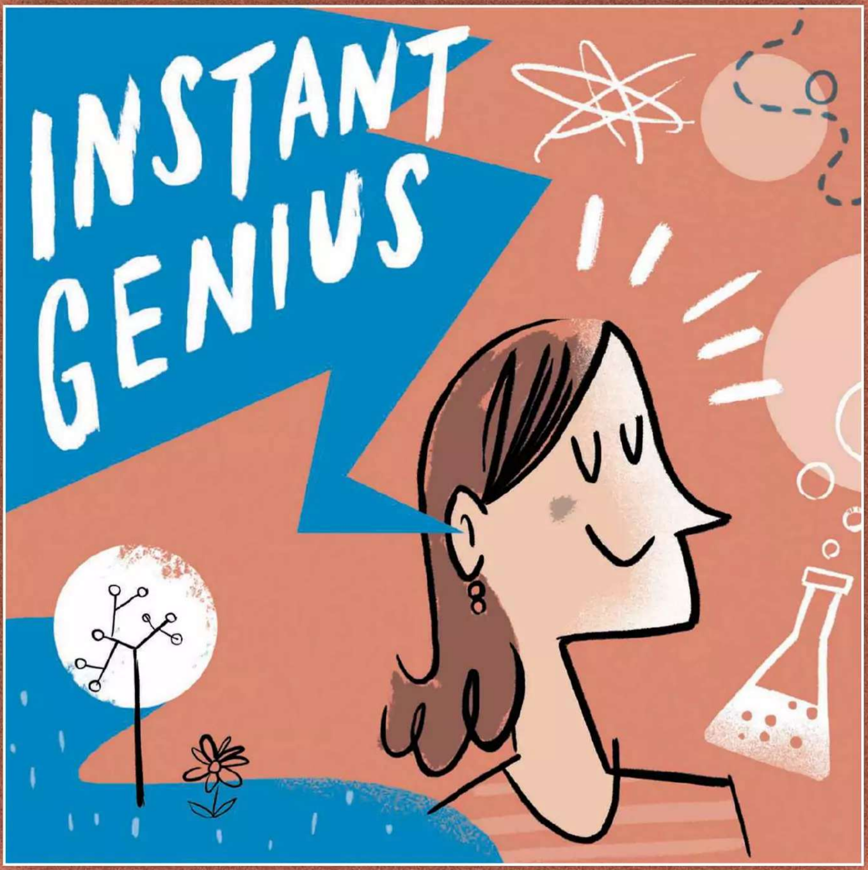

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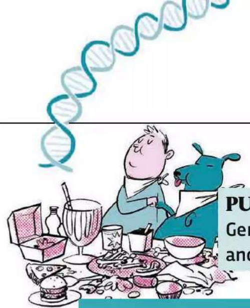
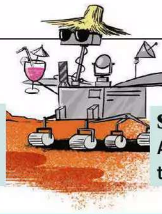


PUPPY FAT
Genes that cause obesity in man and his best friend identified **p20**



SANDCASTLES ON MARS?
Ancient beaches discovered deep below the surface of the Red Planet **p21**

ODD ONE OUT
Scientists find a new way to identify narcissists **p23**

NEWS FROM THE FRONTIERS OF SCIENCE

DISCOVERIES

ARCHAEOLOGY

The strange skeletons that could rewrite the history of the pyramids

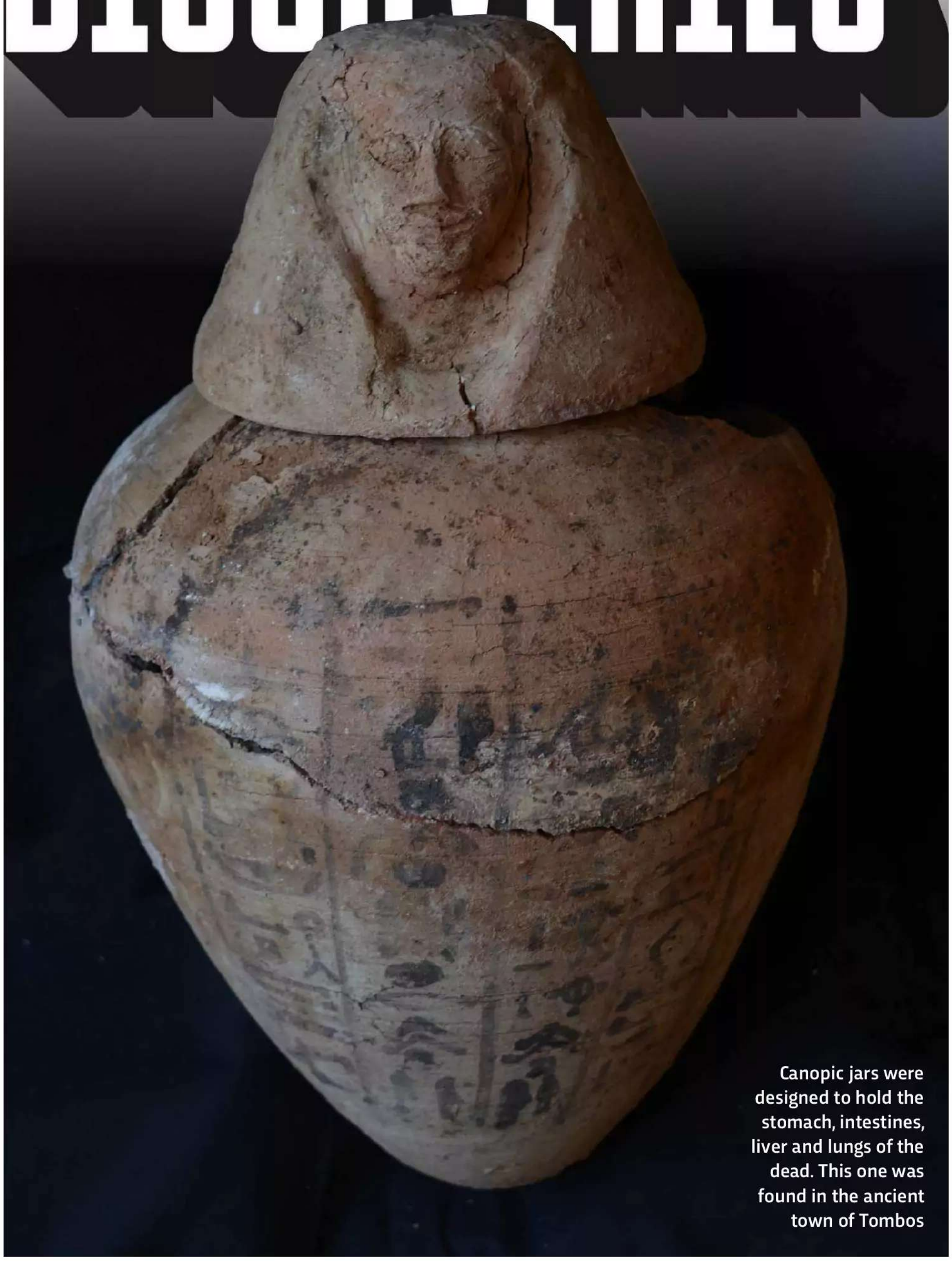
Unexpected evidence found on human remains is shaking up our understanding of ancient burials

For centuries, scientists believed that only the elite were buried in pyramids. But a surprising discovery of ancient skeletons has thrown that idea into question.

In a new study, researchers analysed the remains of people buried in Tombos, an archaeological site located in modern-day Sudan, which borders Egypt.

Around 3,500 years ago, the ancient town of Tombos sat along the Nile River in a region called Nubia. The region was conquered and ruled by the Egyptian pharaoh Thutmose I (whose reign was about 170 years before the infamous Tutankhamun's).

Archaeologists analysed skeletons from several different burial sites at Tombos, looking for subtle marks where muscles and ligaments had been attached to the bones. These traces – called entheseal changes – can give →



Canopic jars were designed to hold the stomach, intestines, liver and lungs of the dead. This one was found in the ancient town of Tombos

DR STUART TYSON SMITH

RIGHT An unfinished statue of a Nubian Pharaoh of the 25th dynasty found near Tombos

BELOW Dr Sarah Schrader, associate professor of archaeology at Leiden University in the Netherlands

> "It wasn't only a super elite, healthy, no-traumatic-lesion sort of environment. There were hard labourers living, working and dying there"

→ archaeologists clues about how a person lived their life by the way it physically altered their bones.

"Entheseal changes can't tell us exactly what these people were doing, but they can tell us if they were more physically active or more like couch potatoes," Dr Sarah Schrader, associate professor of archaeology at Leiden University and the study's lead author, told *BBC Science Focus*.

Some of the skeletons had very few marks, indicating that they lived more sedentary lives and were likely a part of the wealthy noble class. But others, buried in the same pyramids, had markings that suggested they were physically active, which, the researchers concluded, could indicate they were from the poorer labouring classes.

"This could potentially shake up what we know about the pyramids," said Schrader. "In the past, we've just assumed that the people who were buried in there were the elite, because we know that the pyramids were designed for elite people. That still holds true, but maybe there were others being buried in the pyramids as well."

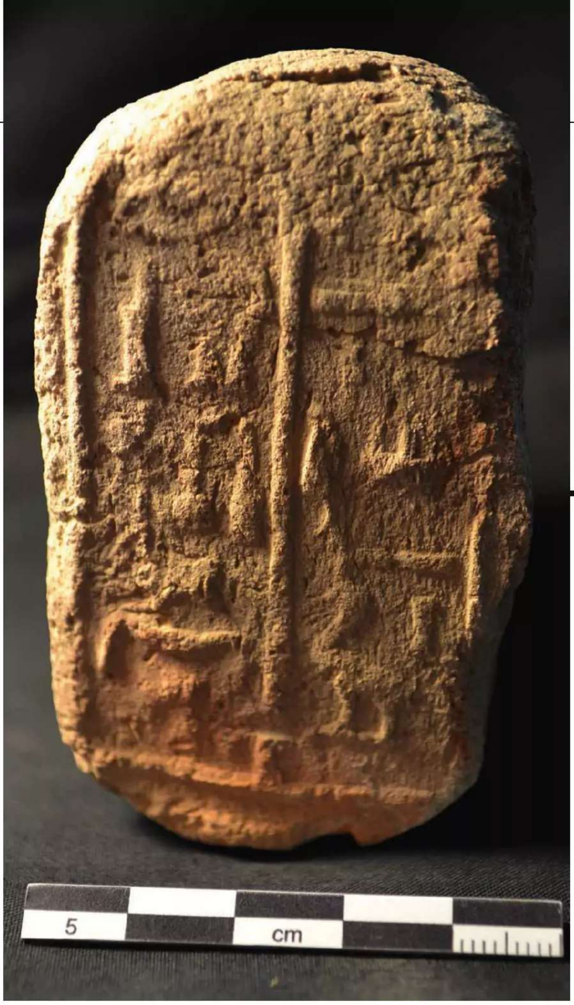
This study was a re-analysis of older findings, originally published in 2012 and Schrader said she hoped it would prompt a re-examination of other skeletal remains found in pyramids.

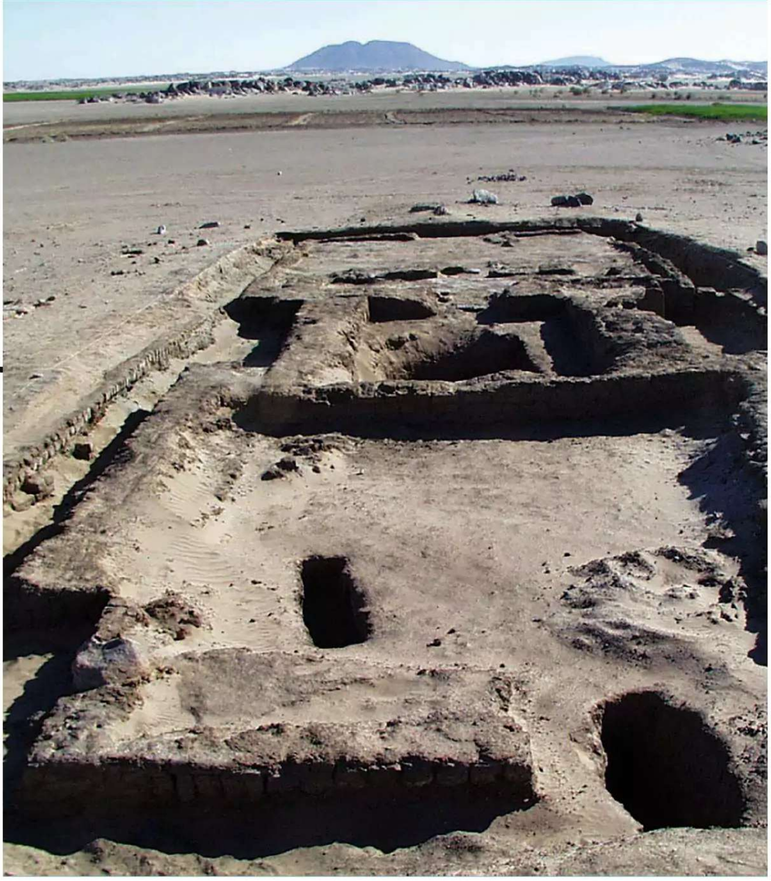
"It may very well be that the same pattern is happening elsewhere," she said. "We can't just assume that things we've done in the past still hold true."

So, how much do we know about the people buried in these Nubian pyramid tombs? A surprising amount, according to Schrader.

"We know their names and the roles they had in colonised Nubia. They're not pharaohs or anything like that, but Egyptians that were brought down from Egypt to Nubia during a colonial period."

ELIZABETH DROLET, DR STUART TYSON SMITH X3





ABOVE Funerary cones, like this one from Tombos, were decorative plates used to mark tombs, stamped with the names and titles of the people buried inside

ABOVE RIGHT An excavated burial site in Tombos

Dr Roland Enmarch – an Egyptologist at the University of Liverpool who wasn't involved with the study – told *BBC Science Focus* that, in this period, pyramids were mostly non-royal structures, rather than monuments for pharaohs and kings.

"We're looking at the later half of Egyptian history, when more impressive non-royal tombs would often have a pyramid as part of the superstructure," he said.

As for the more physically active individuals, Schrader said her team thought these could be "labourers, servants or people who were associated with the high-status individual."

These people would have been placed in the tombs to continue serving their masters in the afterlife, she said. There's no evidence that they were killed to be buried at the same time as their masters, she added, but they were probably buried later, when they died of natural causes.

But that's not the only possible explanation. Some researchers have suggested that these high-activity individuals could have been nobles who chose to stay in good physical shape to reinforce their status.

But this is unlikely according to Enmarch: "I think it's a generally recognised assumption – and it *is* an assumption – that in most societies, people higher up the social scale have less evidence of extreme physical wear."

What complicates the results of the study even more was Tombos's colonial history – a place where Egyptian and Nubian cultures overlapped, intertwined and shaped one another.

Schrader said her team's discovery "might just be a strange Tombos-Nubian thing, but it could also turn out that this was a practice in all the pyramids. We don't know."

Regardless, it sheds some light on who was living in Tombos at that time and the kinds of lifestyles they were leading. Previous archaeological research had suggested that the city's inhabitants lived remarkably comfortable lives.

"[Previous studies indicated] they were very healthy and living to an old age; it really seemed rosy and picturesque," said Schrader.

"We were thinking, what are these people doing? This is a colonial environment and it seems like it's absolutely perfect. The skeletons couldn't be better."

But this re-analysis revealed a more complex picture, she said, and a Tombos with a broader social landscape.

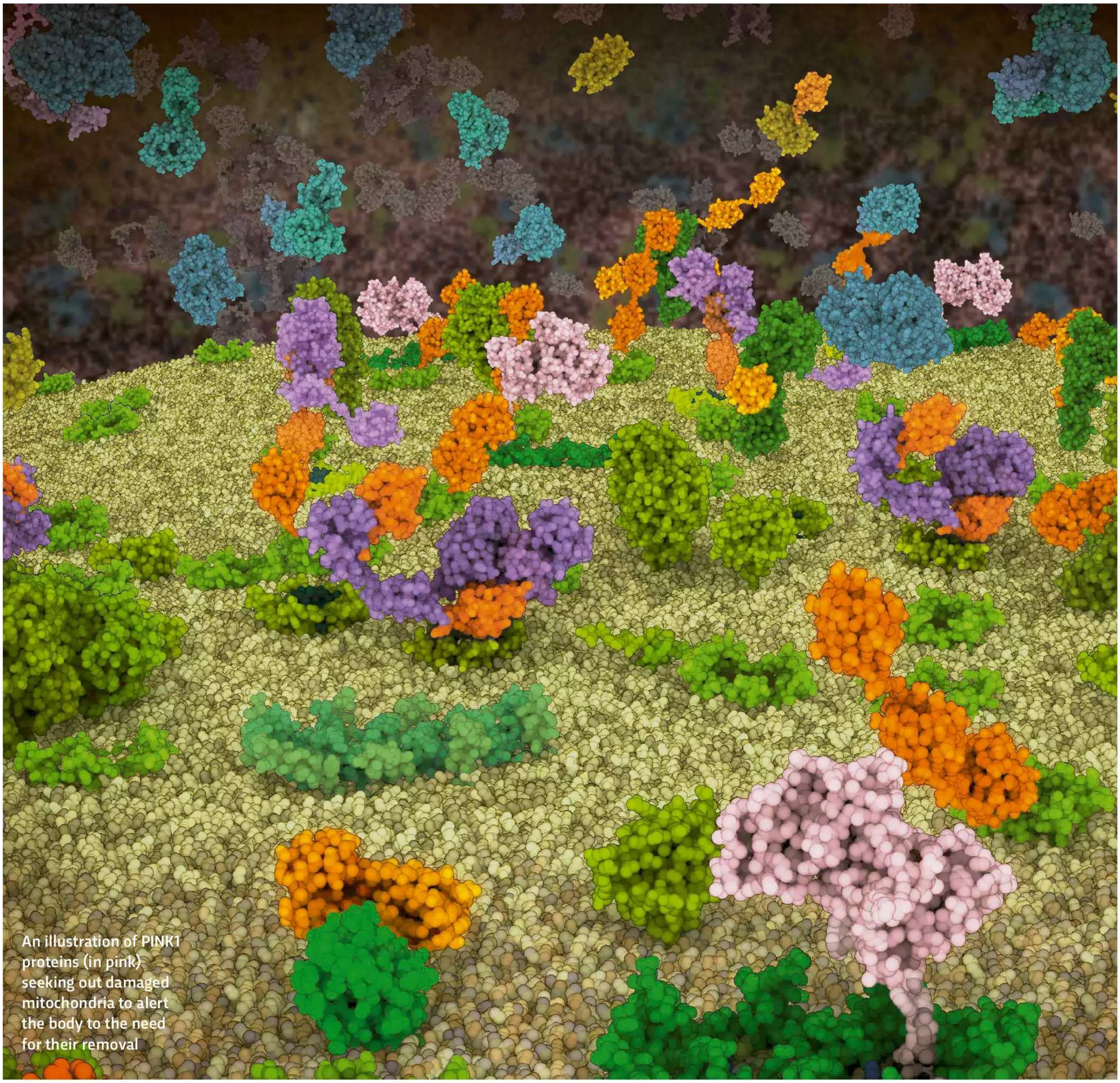
"It wasn't only a super elite, healthy, no-traumatic-lesion sort of environment," said Schrader. "There were hard labourers living, working and dying there."

She said this study provided "some interesting questions for future research" as archaeologists continue to reassess what they know about the pyramids and the people buried inside them.

NEUROSCIENCE

Scientists finally solve key Parkinson's mystery

A newly discovered protein could be the key to developing a treatment for the disease



An illustration of PINK1 proteins (in pink) seeking out damaged mitochondria to alert the body to the need for their removal

ETSUKO UNO/WEHI.TV X2

> **"As the global population ages, the number of people living with the disease is projected to double by 2050"**

Parkinson's is the fastest-growing neurodegenerative disease in the world, affecting around 10 million people globally. It's the second most common neurodegenerative condition after Alzheimer's and, currently, there's no cure. But thanks to a recent breakthrough, scientists hope that new treatments may soon be on the horizon.

Scientists have now linked the disease to a protein called PINK1, produced by the PARK6 gene. Faults in the way PINK1 functions have been directly linked to Parkinson's disease, especially in people with early onset Parkinson's, which accounts for about 1.2 per cent of cases in the UK.

Scientists have recently made strides in understanding how PINK1 interacts with mitochondria. Often called 'the powerhouse of the cell,' mitochondria generate the energy that all living cells need to live.

When mitochondria get damaged, PINK1 notices and signals to the body that they should be removed. But in people with Parkinson's disease, the faulty mitochondria go undetected and accumulate, releasing toxins that eventually kill the cells.

The link between PINK1 and Parkinson's disease has been studied before, but scientists have never known enough about it to help with a Parkinson's cure. Now, researchers at the Walter and Eliza Hall Institute of Medical Research (WEHI) in Australia have worked out what PINK1 looks like, how it's activated and how it interacts with faulty mitochondria, and have reported their findings in a study published in the journal *Science*.

"This is a significant milestone for research into Parkinson's," said Prof David Komander, head of WEHI's Ubiquitin Signalling Division and one of the study's authors. "It's incredible to finally see PINK1 and understand how it binds to mitochondria.

"[Seeing the protein structure like this] reveals many new ways to change PINK1, essentially switching it on, which will be life-changing for people with Parkinson's."

The study's lead author, and WEHI senior researcher, Dr Sylvie Callegari explained that PINK1 works in four distinct steps, the first two of which hadn't been seen by scientists before.

First, PINK1 senses mitochondrial damage. Then, it attaches itself to faulty mitochondria. After that, it signals with a small protein called ubiquitin that the mitochondria need to be removed.

Finally, ubiquitin links to a protein called parkin so that the damaged mitochondria can be recycled in a process called mitophagy.

"This is the first time we've seen human PINK1 docked to the surface of damaged mitochondria, and it has uncovered a remarkable array of proteins that act as the docking site," said Callegari. "We also saw, for the first time, how mutations present in people with Parkinson's disease affect human PINK1."

Parkinson's is a neurological condition. One symptom of the disease is the death of brain cells. We now know this is because the PINK1-mitochondria relationship is particularly important in the brain.

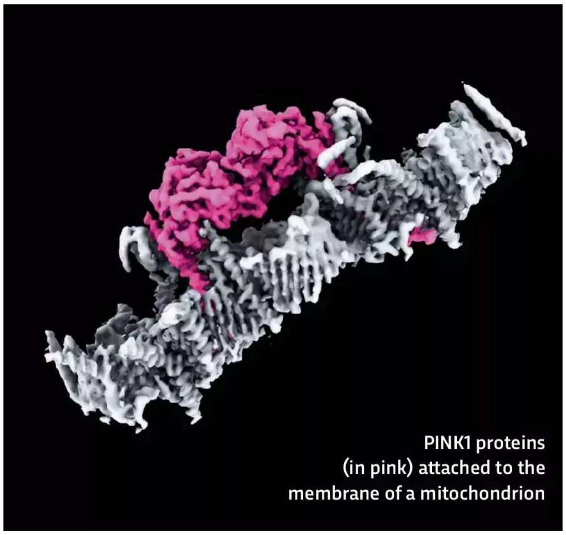
Brain cells need a lot of energy, so they tend to contain more mitochondria than most other cells. That means that brain cells are especially sensitive to damage from toxins released by faulty mitochondria.

When brain cells die, they're also replaced at much lower rates than cells elsewhere in the body, leading to neurological decline.

Parkinson's disease has become twice as common over the past 25 years, according to the World Health Organization and cases are expected to rise even more sharply in the coming decades.

As the global population ages, the number of people living with the disease is projected to reach 25.2 million worldwide. In the US alone, the prevalence is set to increase by 20 per cent, rising from 1 million cases today.

The authors of the new study hope that their research into PINK1 will help speed up the development of drugs and stop the rise of Parkinson's in its tracks.



PINK1 proteins (in pink) attached to the membrane of a mitochondrion

10 MILLION
People worldwide currently affected by Parkinson's disease

1.2
The percentage of Parkinson's cases in the UK that are early onset

25.2 MILLION
The projected number of people worldwide living with Parkinson's disease by 2050

AGEING

We could soon end wrinkles and grey hair forever

Scientists believe they can fight signs of ageing by harnessing your hormones

A new study has identified the potential for a variety of anti-ageing treatments that could prevent the development of wrinkles and grey hair.

Published in the journal *Endocrine Reviews*, the study suggests that naturally occurring hormones could be used to slow some of the body's ageing processes.

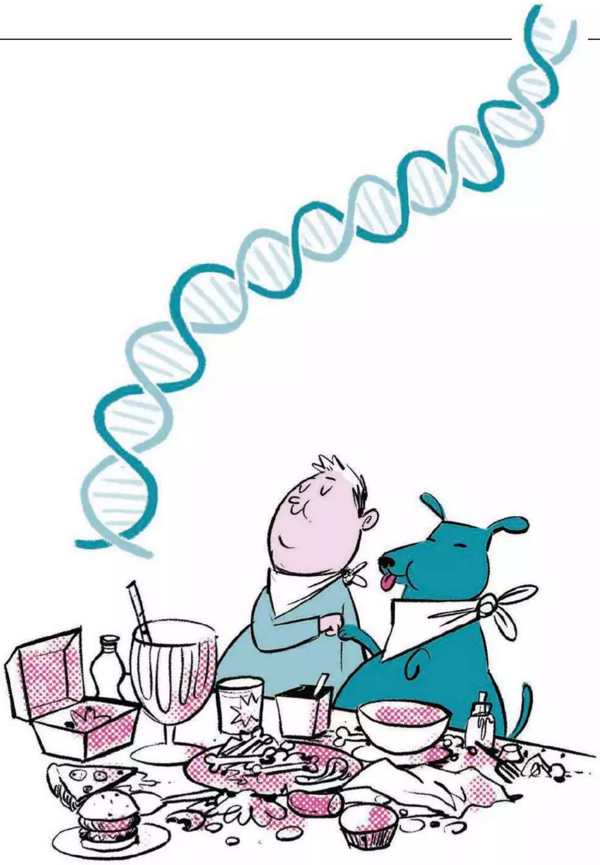
Wrinkling is caused by the degradation of connective tissue, while pigment loss leads to hair turning grey, but key hormones orchestrate these changes.

"Some of the hormones we studied have anti-ageing properties and may be used in the future as agents to prevent skin ageing," said the study's lead author Prof Markus Böhm from the University of Münster, Germany.

The study looked at several key hormones, including oestrogen, growth hormones and melatonin. Among these, melatonin stood out. While most people know the hormone for its role in regulating sleep, the study suggests melatonin may also help keep skin youthful. Its powerful antioxidant effects protect skin cells from damage, potentially slowing down the ageing process.

Several other hormones – including melanocyte-stimulating hormones, which affect skin pigmentation, and oxytocin – were also found to help keep skin and hair youthful by protecting them from UV damage caused by the Sun.

Scientists hope these discoveries will benefit a class of new anti-ageing treatments called senotherapeutics. These drugs work by targeting and removing senescent cells – cells that stop dividing and build up in our bodies as we age – helping to slow down or even reverse some external signs of ageing.



BIOLOGY

'Hungry gene' linked to obesity present in dogs and humans

There's a reason dogs find dieting as difficult as us

Ever wondered why some dogs are always hungry, however much you feed them? Well, we may be close to getting an answer. In a new study, scientists pinpointed several genes linked to obesity in dogs – genes that dogs share with humans. The findings suggest man's best friend could help future researchers unlock new insights into weight gain and complex diseases.

Though environmental factors such as ultra-processed foods are often blamed for rising rates of obesity, scientists emphasise the condition has complex biological causes, including genetics.

ILLUSTRATIONS: ADAM GALE

"If you're unlucky enough to get genes that make you prone to obesity, they manifest as greater appetite, making it harder to resist those drives to overeat," Dr Eleanor Raffan, the lead academic on the study, told *BBC Science Focus*. "Slim people aren't morally superior, they just don't need to exert as much willpower to keep at a healthy weight."

To see if obesity was also hereditary in dogs, the scientists looked at the genes of 241 labrador retrievers – a breed particularly prone to obesity. When compared with humans, the gene DENND1B, which plays a key role in how our cells process energy, emerged as a particularly strong genetic link between human and canine obesity.

As well as offering scientists a new model to understand human disease, this research could also help us take better care of our dogs. Until now the genetic basis of canine obesity hasn't been widely studied.

"Our results underscore the importance of encouraging exercise and limiting food intake for our dogs," said Raffan. "Our data shows that it's much harder to control food intake in the dogs with genes that put them at a high risk of obesity. That should change how we address canine obesity: we need to target owners of high-risk dogs and offer them support on effective management, rather than blaming them."

"Slim people aren't morally superior, they just don't need to exert as much willpower to keep at a healthy weight"

SPACE

Beaches on Mars are clearest evidence of ancient life

They're not like those in the Caribbean, but the Red Planet's beaches may still have attracted microbial tourists

New research suggests that not only was Mars once a perfect holiday destination (if you're willing to overlook the radiation exposure and absence of food sources), but was also in possession of the right conditions to host alien life.

It all stems from the discovery of ancient sandy beaches on Mars. A discovery that suggests a large liquid ocean once spread over the northern part of the Red Planet.

The team behind the research, from institutions in China and the US, says that this ancient shoreline is the clearest evidence yet that Mars was previously habitable.

"When we look back at where the earliest life on Earth developed, it was in the interaction between oceans and land. So this [discovery] is painting a picture of ancient habitable environments capable of harbouring conditions friendly toward microbial life," said Benjamin Cardenas, assistant professor of geology at Pennsylvania State University and one of the researchers on the team. "We found evidence for wind, waves, no shortage of sand – a proper, vacation-style beach."

The researchers used the radar imaging equipment aboard China's Zhurong rover to probe the ground beneath Utopia Planitia on Mars. The scans picked up 76 hidden formations buried 10–35m (33–115ft) below the surface that the evidence suggests were produced by sedimentary deposits.

The shape, thickness and length of the Martian deposits indicate that they were not formed by lava or ice melting, but rather by a stable ancient ocean. In fact, they're almost identical to formations found in 21 locations on Earth, including the Bay of Bengal in the Indian Ocean.

Formations such as these are called 'foreshore deposits'. The ones detected beneath the Martian surface slope down at an angle of 15° towards what was once an ocean and were formed by tides carrying sediments like sand and gravel.

"We tend to think about Mars as just a static snapshot of a planet, but it was evolving. Rivers were flowing, sediment was moving, and land was being built and eroded," said Cardenas.

"This type of sedimentary geology can tell us what the landscape looked like, how it evolved and, importantly, help us identify where we would want to look for past life."

ENERGY

Massive new energy source could be hiding in Earth's mountains

Hydrogen gas is generated along fault lines in a process that takes millions of years

Scientists may have found a new energy carrier that could help with our efforts to transition away from fossil fuels – and it could be lurking in the mountains. Using advanced simulations, a German research team think they've found vast reserves of clean hydrogen gas (H_2) produced by rocks that are millions of years old.

As an energy carrier, H_2 is more sustainable than fossil fuels, which release greenhouse gases and cause climate change by trapping heat in the atmosphere. Yet currently, our predominant method of producing H_2 is through a synthetic process that, ironically, requires fossil fuels.

The major obstacle to natural H_2 extraction has been finding a reserve large enough to be viable. The research team's findings could change that. "Overall, we may be at a turning point for natural H_2 exploration," said Dr Frank Zwaan, one of the team members. "As such, we could be witnessing the birth of a new natural hydrogen industry."

The most promising natural method for large-scale production of H_2 is through a geological process known as 'serpentinisation', which refers to how rocks from deep in Earth's mantle react with water. Essentially, the minerals in these rocks undergo chemical transformations, forming new minerals that belong to the serpentine group and releasing H_2 gas in the process.

The researchers think that when these rocks are found near Earth's surface they could create significant hydrogen-rich zones. To get to the surface, the rocks are 'tectonically exhumed' through more than 2,900km (1,800 miles) of mantle over millions of years. This process occurs through two main mechanisms: continents breaking apart (allowing the mantle to rise) and the formation of mountains (pushing mantle rocks up to the surface).

When researchers modelled the two processes, they found that mountain formation created the best conditions for serpentinisation. In fact, their simulations showed that rocks emerging through mountain formations promised 20 times more H_2 capacity than those pushed to the surface through continent rifting.

Researchers have already found indications of natural hydrogen generation in mountains including the Pyrénées, Alps and Balkans.

HEALTH

Science can now measure your brain's 'biological age'

A combo of brain scan techniques delivers a breakthrough for dementia research

Biological ageing tests have, so far, been unable to reveal how old your brain is. But a recent study may have found a new way to calculate how fast your grey matter is ageing – and it could help predict and prevent dementia.

Unlike your chronological age (the number of years since you were born), your biological age depends on how worn down your cells and tissues are. Two people can be the same chronological age, but have different biological ages.

Most of the time, biological age is measured via DNA methylation – a chemical process that changes how your genes look at the cellular level. But researchers at the University of Southern California noted that this method doesn't work for our brains.

ILLUSTRATIONS: ADAM GALE

PSYCHOLOGY

How to spot a narcissist, according to science

Narcissists are more likely to feel socially excluded

A new way of telling whether someone is a narcissist has been revealed. Published in the *Journal of Personality and Social Psychology*, the new study found that narcissists are more likely to feel left out than the average person and are more sensitive to subtle social cues.

"Feeling ostracised is a subjective experience based on the perception of social cues by the individual. Some may be intentionally ostracised, while others may merely believe they're being excluded when that's not the case," said the study's lead author Dr Christiane Büttner, from the University of Basel.

"Our findings suggest that individuals with higher levels of narcissism are more sensitive to exclusion cues, leading them to perceive ostracism more frequently."

Büttner's team analysed data from multiple surveys, including a multi-year German study of 1,592 participants. The results showed that people with higher levels of narcissism were significantly more likely to feel excluded in daily life.

The researchers then studied 2,500 people with varying levels of narcissism, designing activities that simulated social exclusion – not being chosen for a team in a sports game, for example – to see how they would react.

People with stronger narcissistic traits were more likely to interpret being ignored as intentional rejection. They also tended to overestimate how many times they were excluded.

"If people with high narcissistic traits are more likely to feel and be excluded, this could contribute to escalating tensions in workplaces or social groups. At the same time, their heightened sensitivity to exclusion might make them more likely to react aggressively," Büttner said.

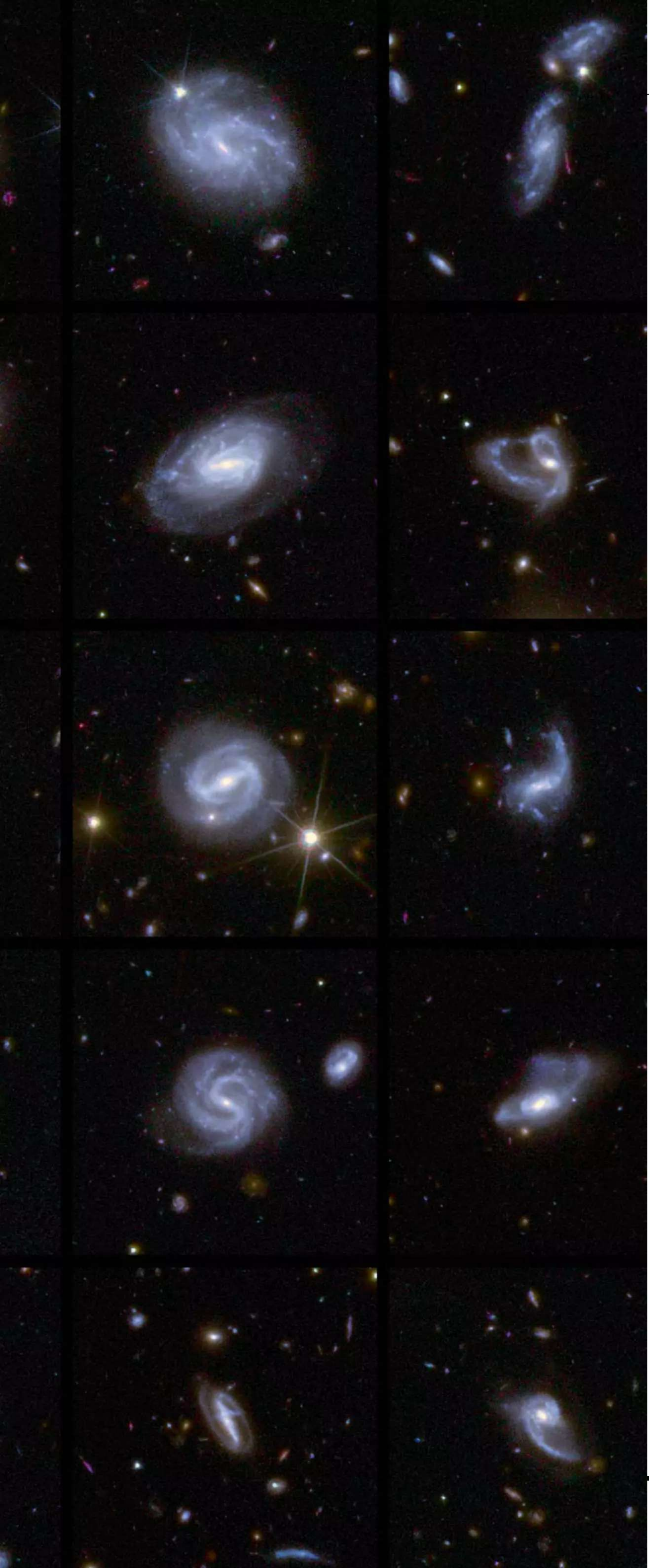
> **"Their heightened sensitivity to exclusion might make them more likely to react aggressively"**

That's because the blood-brain barrier doesn't allow blood cells to cross into the brain. So a blood sample taken from elsewhere in your body can't reveal anything about your brain, but getting samples directly from the brain is too risky.

To overcome these obstacles, the researchers created a non-invasive method by training an artificial intelligence (AI) model to compare baseline and follow-up magnetic resonance imaging (MRI) scans. The contrast between the scans showed which brain zones were ageing fastest.

"This could change the way we track brain health, both in the research lab and in the clinic," said Prof Andrei Irimia, senior author of the study. "Knowing how fast one's brain is ageing can be powerful." When testing this model on Alzheimer's patients, the researchers found that people experiencing faster brain ageing were more likely to have reduced memory and processing speeds.

The researchers think their AI model can make accurate predictions about dementia trajectories, helping doctors choose the best treatments for their patients.



SPACE

Stunning new cosmic map reveals Universe's weirdest phenomena

The Euclid space telescope has captured millions of galaxies in astonishing detail

The European Space Agency's (ESA) Euclid space telescope mission has released its first survey images, offering a stunning glimpse into the vast cosmos.

The new pictures, taken in a 63-square-degree patch of sky – that's an area more than 300 times the size of the full Moon – reveal millions of galaxies in exquisite detail, alongside celestial phenomena such as gravitational lensing.

Predicted by physicist Albert Einstein over a century ago, gravitational lensing happens when massive objects like galaxies warp the fabric of space-time. This bends the light from the even more distant galaxies behind them, making far-off galaxies appear as glowing arcs around the closer ones.

Euclid captured 500 of these dramatic lensing events in just one week. By studying the shape and brightness of these arcs, scientists can map the hidden dark matter surrounding galaxies and even gather clues to find out what it's really made of.

Launched in July 2023, the telescope is designed to survey a third of the sky and will ultimately image 1.5 billion galaxies. A week of deep-field observations can identify as many as 26 million galaxies, with some being as far as 10.5 billion light-years away.

In October 2026, ESA will release Euclid's first cosmology dataset, incorporating a much larger survey area and more deep-field passes.

ESA/EUCLID/EUCLID CONSORTIUM/NASA IMAGE PROCESSING BY M WALMSLEY/M HUERTAS-COMPANY/J-C CUILLANDRE

COMMENT

The race to find a better way to diagnose endometriosis is heating up

It's vital we improve our ability to identify cases of endometriosis, for the sake of women everywhere

Endometriosis is a common condition where cells similar to those in the lining of the womb grow in other parts of the body.

It affects around 10 per cent of women, and up to 50 per cent of women who are infertile, and can have a significant impact on their quality of life. Yet, it remains very difficult to diagnose. Currently, a diagnosis takes, on average, almost nine years and that figure is increasing.

There are several reasons for this. But the main one is that the symptoms of endometriosis, which include bloating, pelvic pain and painful periods, can be present in a number of other conditions, such as fibroids, ovarian cancer, pelvic inflammatory disease and irritable bowel syndrome.

Currently, the gold-standard test is a diagnostic laparoscopy. It takes place under general anaesthetic, during which a small camera is inserted into the patient (typically through an incision near their belly button) to view their pelvis and abdomen.

This way, the body's internal cavities can be inspected, and any endometriotic lesions or cysts (endometriomas) can be identified and assessed.

In addition to being invasive, painful and costly, the procedure isn't 100-per-cent accurate. Endometriotic lesions can be confused with other types of lesions, and only biopsies can deliver definitive results.

Often, a diagnostic laparoscopy carried out without biopsies can lead to unnecessarily prolonged medical treatment and operations, and may even delay the correct treatment being administered.

To combat this, several research teams are racing to develop a more effective endometriosis test – one that can detect all forms of the disease and deliver faster diagnoses, while being both affordable and comfortable for patients.

DR MICHELLE GRIFFIN

Michelle is the director of MFG Health Consulting, as well as a women's health expert and strategy advisor in women's health tech.

One recently launched option is the Ziwig Endotest. Developed by a French research group, it's a saliva-based test that works by sequencing 109 microRNAs and using artificial intelligence to analyse and compute the results. It's reported to detect endometriosis at an early stage with a sensitivity of up to 97.4 per cent in women aged 18 to 43 with one or more symptoms that could be related to endometriosis.

MicroRNAs are small fragments of ribonucleic acid that are involved in regulating when certain genes are 'switched on or off'. This test exploits the link between certain microRNAs and the development of endometriotic lesions. The team has been able to develop this from a blood test to a saliva test.

Another promising development is the PromarkerEndo blood test. Developed in Australia, this test looks for the presence of 10 proteins associated with endometriosis. It has been shown to have up to 99.7-per-cent accuracy in patients with the most severe form of endometriosis and more than 85-per-cent accuracy in catching the disease in its early stages.

It has also been shown to be highly accurate in confirming that women showing some symptoms of endometriosis don't have the disease.

Both these tests are still yet to be fully adopted by healthcare professionals and much more data needs to be collected to prove their real-world efficacy. Nevertheless, the ability to definitively tell a patient whether they do or don't have endometriosis is a significant development.

Elsewhere, Hera Biotech is developing the MetriDx test, which analyses multiple genes linked to endometriosis. This could replace the diagnostic laparoscopy by taking a biopsy from the womb to provide a direct diagnosis. While it is more invasive than a blood or saliva test, it doesn't require surgery.

The early results for MetriDx are promising: the test has an overall accuracy of 94 per cent and demonstrates robust accuracy in diagnosing different stages of the disease.

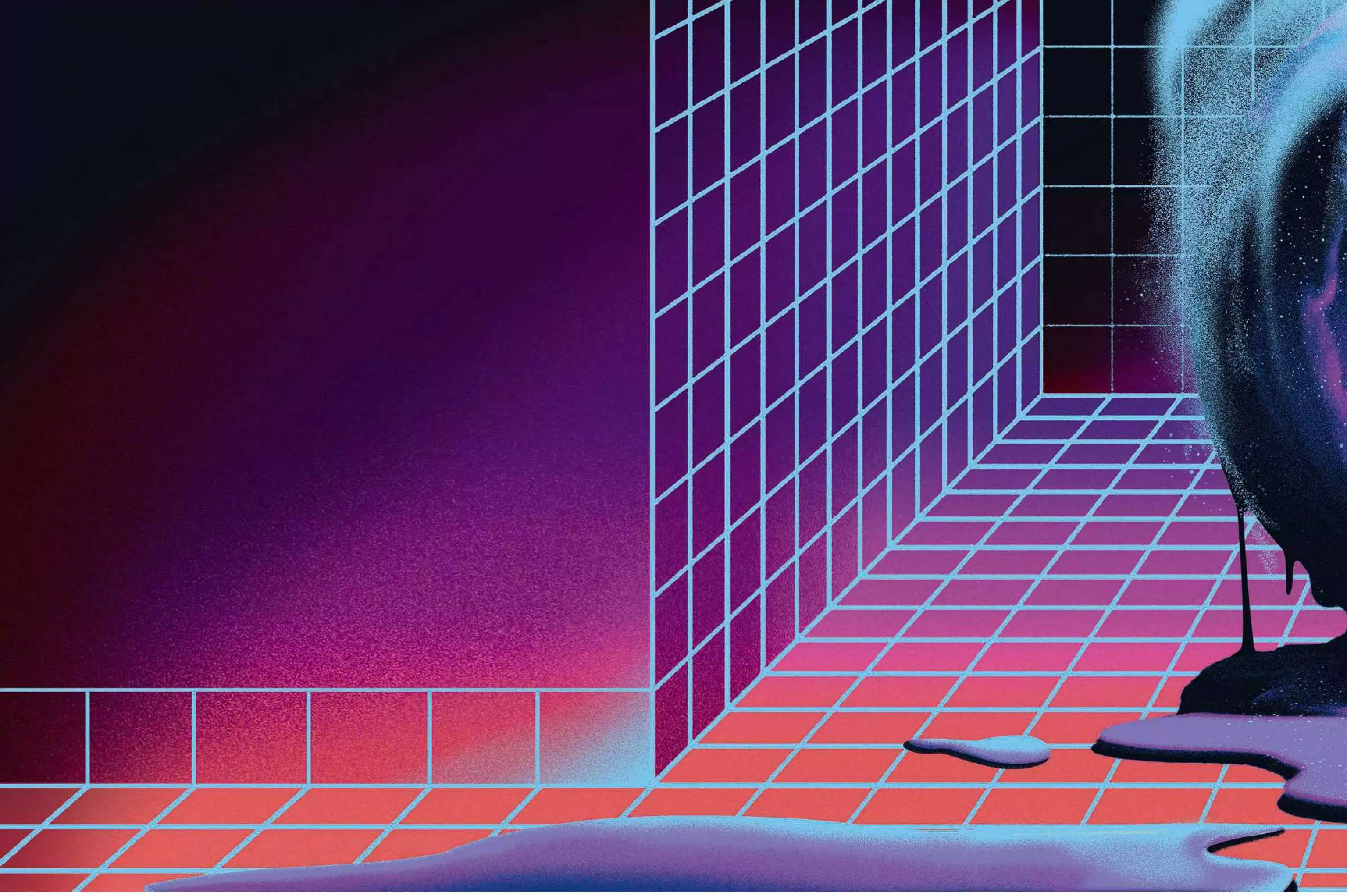
Another approach is to use imaging tools like ultrasound and MRI, which, while important for endometriosis care, often miss lesions. The University of Oxford and Serac Healthcare are developing a new technique using a novel marker named ^{99m}Tc-maraciclatide, which attaches to inflamed tissue.

This method better identifies superficial endometriosis in 80 per cent of cases, deep endometriosis and endometriomas, and has even found lesions that ultrasound scans missed.

All this represents critical progress towards transforming patient care by dramatically reducing the diagnostic delay and potentially improving the quality of life for millions of women worldwide.

> "Currently, a diagnosis takes, on average, almost nine years and that figure is increasing"

ILLUSTRATION: KASIA KOZAKIEWICZ



COMMENT

Freeze your brain if you want, but you won't be *you* …even if they can thaw it out

The chances of successfully cheating death by having your head cryogenically frozen remain sub-zero

Perhaps inevitably in such turbulent, uncertain times, there's a renewed interest in cryonics: the freezing and storing of human remains so that they can be resurrected in the future when medical technology is sufficiently advanced.

The appeal of this is obvious. It's basically the mortality equivalent of a video game save point, allowing you to 'undo' whatever life-ending harm you've experienced and pick up where you left off.

But a growing enthusiasm for cryonics doesn't change the fact that, at present, it's a process with many significant hurdles to overcome before it could be said to 'work', in any meaningful way.

Cryogenically freezing someone is rarely, if ever, permitted before that person has died. Why? Because freezing a living body is inherently a lethal process and, even if they're okay with it, it's illegal to kill a person.

It's often said that the human body is mostly water. Water makes up the bulk of the vital fluids that keep our cells and tissues alive and functional.

When you freeze water, however, it turns to ice. Solid, expansive, spiky ice. If living cells are suddenly filled with it, ice does a lot of damage. This is why freezing and thawing things like strawberries renders them mushy – the cells that give strawberry flesh its structure are badly disrupted.

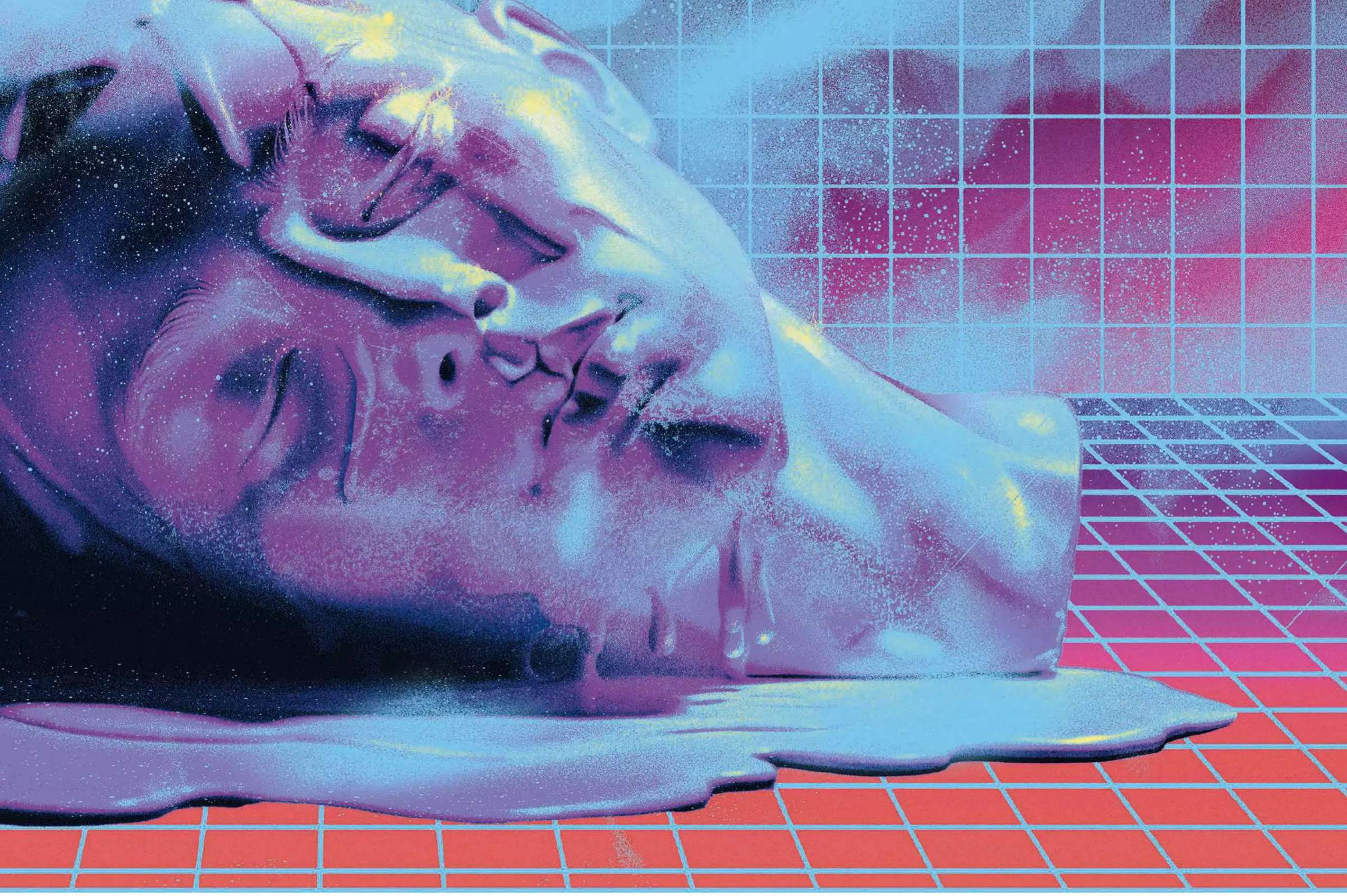
And that's a piece of fruit. A human body is far more complex, sustained by countless different tissues and delicate biochemical processes.

There are ways around this. The speed of freezing can reduce the presence of ice crystals, as can the inclusion of cryoprotectants (chemicals that prevent or reduce the cellular damage done by freezing).

While such approaches can work for individual cells or tissue samples such as embryos, the more cryoprotectants are needed, the more toxic they become to the delicate chemical processes that sustain life. So, the larger and more complex an organism is, the harder it is to freeze 'safely'.

More importantly, no sufficiently complex living organism is ever fully inert. It's always biologically active, being sustained by innumerable biochemical processes. Freezing shuts these down. Turning them back on again isn't like flicking a switch on a machine, but more like trying to unscramble an egg.

ILLUSTRATION: ANDREI NICOLESCU



> **“The internal structure of a neuron is also very intricate and far more vulnerable to chemical and physical damage”**

While not impossible with sufficiently advanced technology, it’s certainly not easy.

Many prospective ‘cryonauts’ freeze only their head or brain. Presumably because, if medical science has advanced enough to defrost your noggin, it’ll be just as able to replace the body that was once attached to it. And as long as your brain is intact, you’re still ‘you’, right?

But freezing and restarting the brain is likely the biggest challenge of all. Because neurons – the brain cells that form the biological basis of everything that you are – are significantly more intricate and vulnerable than any other type of cell.

For one thing, neurons and brain cells are the most metabolically demanding; they consume about a quarter of the body’s available energy just to stay alive. A frozen body has zero available energy. Consider that a stroke is what happens when the blood supply to just one part of the brain is disrupted, even briefly.

The internal structure of a neuron is also very intricate and far more vulnerable to chemical and physical damage. Also, while other tissues may be able to regenerate or repair damage caused by a less-than-perfect cryogenic process, neurons struggle to do this. So, the brain is both more vulnerable to harm from the cryogenic process and less able to recover from it.

And this is key. It’s not just the presence and number of neurons that support our minds and consciousness, but the exquisitely precise and sophisticated way in which they’re arranged and linked. The typical brain contains trillions of spindly microscopic neuronal connections, which are how our memories and identities are stored. Such fundamental connections would be very easily wrecked by the freezing process.

Even if future medicine could rebuild and restore these connections, how would a future neurologist know what connections go where? Unless you have a full molecular-level brain scan before you’re frozen, and that scan is stored with your head or body, trying to rebuild neuronal memories would be like trying to rewrite a burned book by studying the ashes.

Basically, however it’s set up or applied, every modern manifestation of cryonics relies on one vital resource: optimism. And while there’s nothing wrong with that per se, you’d hope people would think twice before gambling their lives on what is currently a very unlikely outcome.

DR DEAN BURNETT

Dean is a neuroscientist and author. His latest book, Why Your Parents Are Hung-Up on Your Phone and What To Do About It *is out now (Penguin, 2024).*

-Mempathie-

COMMENT

Some scientists think insect populations are increasing. Here's why they're wrong

The debate over the misleading results of a flawed study raises questions about how biodiversity loss should be measured

Back in 2020, when French scientists, Drs Laurence Gaume and Marion Desquilbet, first heard the news about a new international insect decline database, they felt something was off. It suggested that some insect species were actually on the rise – a claim that contradicted years of research.

"We were concerned. We felt the conclusions were over-optimistic," says Desquilbet, an environmental economist at Toulouse School of Economics. "It went against prior results clearly pointing to a decline in insect biodiversity."

When I talk to them five years later, old concerns about mistakes in the insect database shine a light on new, big-picture qualms about how biodiversity is measured. But more than that, whether scientific discovery should be up for debate.

The database they were initially concerned with was called InsectChange and merged various other datasets created by researchers. In 2020, scientists from Germany, Russia and the US published an analysis of InsectChange, examining its data and findings.

"We've been convinced that simplified narratives are the desired 'norm' for science"

The main takeaways were that while insects on land weren't doing well, declining at a rate of nine per cent per decade, freshwater insects were making a comeback – increasing at 11 per cent per decade. It made the picture of worldwide insect decline look much more nuanced than previously thought.

The findings left some scholars scratching their heads, as other research suggests insect decline is continuing at a far greater pace. In fact, more than 60 scientists published letters saying they had concerns with the results. The database's team issued some corrections to the data and chalked others up to misunderstandings or differences in opinions.

"We kept feeling concerned about the impact of the publication," says Desquilbet. After all, the decline paper is cited 1,112 times in scientific journals and books, while their feedback is quoted just 60 times.

Guame and Desquilbet dug into the dataset themselves and claimed to uncover over 530 methodological and statistical mistakes. Almost all datasets, 161 out of 165, had at least one issue, they said.

For one, the database gathers datasets with all sorts of different units of measurement, but then applies a faulty mathematical transformation that doesn't yield the real percentage of insect change per year, according to Gaume, an insect ecologist at Montpellier University.

Datasets about aquatic insects also include non-insect invertebrates, such as mussels, snails, worms and crustaceans. For instance, data from a lake in Kazakhstan suggest that insects have increased over the past century, but include invasive mussel blooms, which make up 95 per cent of the invertebrates in the lake.

Most of the datasets also came from rewilding projects with the end goal of increasing insect populations through methods such as building artificial ponds. These environments have been manipulated and so don't represent a natural insect habitat. "The user is left unaware of the biases," says Gaume.

The InsectChange team heard the concerns loud and clear. "There are mistakes in our data," says database creator Dr Roel Van Klink, an ecologist at the German Centre for Integrative Biodiversity Research. "Like there are mistakes everywhere."

The team is working to incorporate corrections and update the database to make it as accurate as possible, as well as expanding it. They aim to publish a new and improved version of the database in the next six months.

They also asked Gaume and Desquilbet to work on the project, but the pair refused.

"The real question is, does it matter for the outcome of the analysis? I say it doesn't," says Van Klink. "The results wouldn't be different if all of these tiny mistakes were weeded out." He also notes that not separating insects from invertebrates in the freshwater data collection was a choice he and his team made.

Still, this InsectChange debacle tells a wider story. In the era of the biodiversity crisis, scientists are scrambling to measure what's happening to nature and determine trends of what might happen next. These huge databases are hard to cross-reference and keep in check as more and more information is added.

Every study has flaws, limitations, and biases. "These complexities and limitations are rarely discussed because we've been convinced that simplified narratives are the desired 'norm' for science communication," says Dr Manu Saunders, an ecologist from the University of New England, in Australia, who wasn't involved in either of the studies.

That's why, Saunders says, scientists should continue to engage in debate. Just because the research was published doesn't mean its scientific pursuit is over. Science is a method not a finished product.

SOFIA QUAGLIA

Sofia is a freelance journalist who specialises in writing about biology and nature.

ILLUSTRATION: MARTA LANZA

REALITY CHECK

THE SCIENCE BEHIND THE HEADLINES

REVIEW

Cycle syncing has the potential to change lives

Adapting to hormonal fluctuations throughout the menstrual cycle could be a secret weapon in the fight against breast cancer

BBC

For more fact-checking news, visit the BBC's Verify website at ***bit.ly/BBCVerify***

Cycle syncing is having 'a moment.' The practice, which involves women adjusting their habits to align with their menstrual cycle, is all over the digital realm.

Menstrual tracking apps – Clue and Flo are just two examples of the many available – are popular. Downloaded to phones, smartwatches and other wearable tech, they're currently used by an estimated 50 million people. Most women use them to track their periods and understand their cycles. On social media, however, cycle syncing is touted by influencers as a means to enhance fitness, help you lose weight and even boost your creativity.

There's scant evidence to back those claims, however. Research published this year from McMaster University, in Canada, for example, found no link between synchronising menstruation phases and exercise routines with the body's ability to build muscle and strength. It hasn't stopped #cyclesyncing from notching up more than 500 million views on TikTok, but it has drawn attention away from another application for cycle syncing: making drugs and medical tests work better.

> "The female body was considered too complex and variable"

For drugs to be authorised for use, they have to first be tested in clinical trials. Before the 1990s, however, women were largely excluded from these trials because, it was thought, their fluctuating hormones would cloud the results. The female body was considered too complex and variable, and so most of the studies were done on men. Even female animals were often omitted from laboratory research for the same reasons.

This has changed now, but the effects of the menstrual cycle on drug response remain murky. It's known, for example, that certain painkillers, such as morphine, are more or less effective at different points in the cycle. Beyond that though, little is known.

"This area has been very overlooked," says Dr Colinda Scheele from the VIB-KU Leuven Center for Cancer Biology, in Belgium. Scheele is a cancer biologist. She became interested in cycle syncing when she was studying how mice with breast cancer respond to chemotherapy. Sometimes the treatment worked well, sometimes less so, with little obvious rhyme or reason to the pattern. Scheele and the female researchers she worked with at the time, wondered if the animals' hormonal cycles were having an effect.

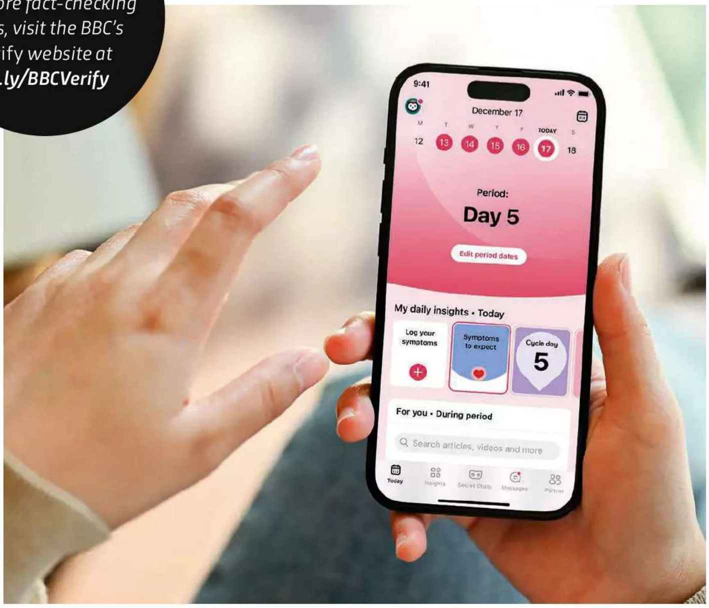
Mice may not have periods, but they do have a four-to-five-day hormonal cycle called the oestrus cycle. In 2024, Scheele did a study where she gave mice chemotherapy at different stages in their oestrus cycles. When the treatment was given in the first half of the cycle, when progesterone levels were low, it worked better than when it was given in the second half, when progesterone levels were high. Cells were less resistant to chemotherapy and the tumours shrank up to three times more in size.

Encouraged, Scheele did a follow-up study where she looked at archived blood samples taken from women with breast cancer who were treated with chemotherapy. By analysing the samples, Scheele could tell where in their cycle the women were when they had their treatment. And from their clinical records, she could tell how they responded to the treatment. Chemotherapy was found to be better at shrinking breast cancer when it was given in the low progesterone, or 'follicular', phase of the menstrual cycle, compared with when it was given in the high progesterone, or 'luteal', phase.

The implications of the work are huge. If Scheele's results hold up, and can be replicated in a bigger study that she's already organising, then chemotherapy could be made more effective simply by cycle syncing. Waiting for a week or two, until progesterone levels fall, could help to banish breast cancers.

"It's such a simple thing to do. It's not giving an extra drug or doing anything invasive," says breast cancer researcher Dr Wendy Ingman from the University of Adelaide, who wasn't involved with the research. "The potential for improved survival is there."

Remarkably, timing just the first dose of chemotherapy was enough to have an effect. This is important because when women have multiple doses of chemotherapy, it can cause their periods to stop. Timing the first dose appears to prime the response to subsequent ones. →



ABOVE Period tracking apps are useful for getting an idea of where you are in your menstrual cycle

LEFT Hormonal fluctuations during the menstrual cycle could alter the efficacy of certain medical treatments

GETTY IMAGES, FLO

> **“These and other differences may help to explain why sensitivity to chemotherapy varies with the menstrual cycle”**

→ Cycle syncing also worked for different subtypes of breast cancer, including those known to respond to ovarian hormones and those that don’t. This suggests that something other than hormones might be at play.

In her mouse studies, Scheele has noticed that when chemotherapy is given in the favourable, low progesterone phase, blood vessels around the tumours get a little wider. “This suggests that more blood and potentially more chemotherapy can get to the tumour,” she says. There are also lower levels of immune cells, called macrophages, which can otherwise limit the effectiveness of chemotherapy. These and other differences may help to explain why sensitivity to chemotherapy varies with the menstrual cycle.

ALL ABOUT THE TIMING

It’s not just breast cancer treatments that could benefit from cycle syncing, either. The usefulness of the tests that guide those treatments could also be improved by cycle syncing.

Ingman’s work focuses on certain genetic tests that are given to women who have breast cancer before they begin treatment for it. The tests, which assess patterns of gene expression, are designed to predict the aggressiveness of their particular cancer and the best treatment option for it.

Ingman has analysed how patterns of gene expression change over the two-week period between the initial breast biopsy and the surgery that follows. She has found that young women with active menstrual cycles have more variation in gene expression than older, menopausal women. In mouse studies, she has also shown that patterns of gene expression are different in different stages of the oestrus cycle.

“This suggests that the genes being used for profiling tests, which then guide treatment decisions, could be affected by the stage of the cycle that a woman is in when she has the test,” says Ingman.

Put simply, if a woman has the test at one stage in her menstrual cycle, she may be recommended different treatment options than if she had it at a different stage. There may be an optimal time in the menstrual cycle for the test to be given and if clinicians can’t change the timing of the test, then it may be possible to adjust the test itself to accommodate these hormonal changes.

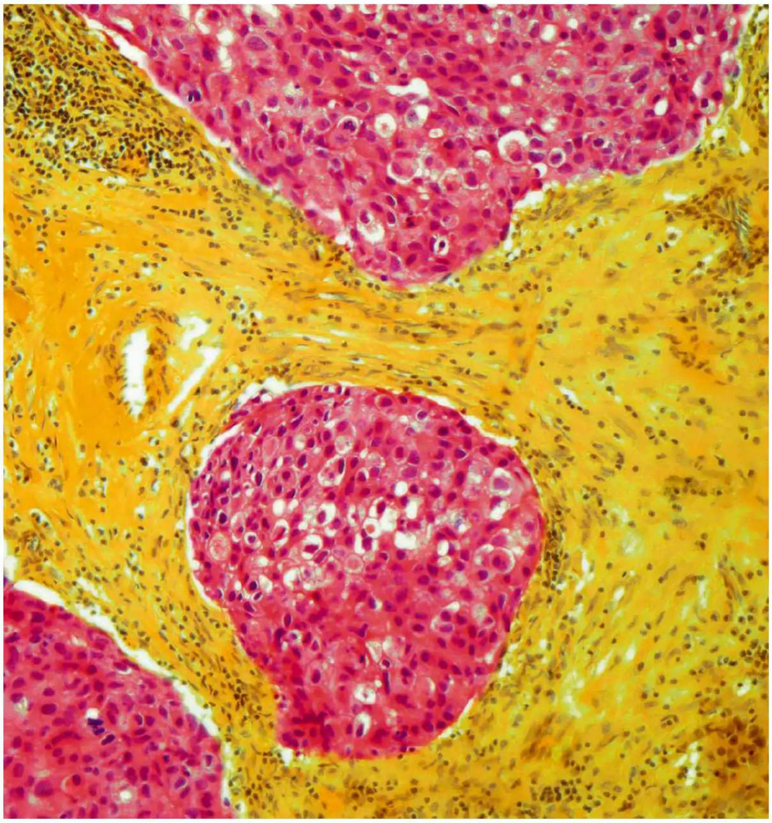
MORE TO LEARN

For now, the proposed benefits of cycle syncing for breast cancer are still being ironed out, but if the practice is found to make a reliable difference, then research into other interventions will follow. It may be that cycle syncing makes a difference in the way that other diseases are treated too.

Some researchers are sceptical, however. There’s more to the menstrual cycle than just hormones, points out menstrual health researcher Dr Sally King from King’s College London. If timing turns out to be important, then so too could other factors, such as inflammation and the activity of the immune system. Both of these factors are known to change through the cycle.

There are also significant differences between the mouse oestrus cycle and the human menstrual cycle, which make comparisons tricky. What’s needed, King says, is more research into the menstrual cycle and an updated appreciation of its intricate biology.

In the meantime, tracking your menstrual cycle, if you have one, is still a good thing to do. “Women need to know what’s normal for them because everybody’s ‘normal’ is different,” says King. In other words, don’t pay too much attention to the influencers who make claims unsubstantiated by evidence, but do pay attention to your body, because its rhythms could be more important than you realise.



BELOW Breast cancer, seen under a light micrograph

GETTY IMAGES X2

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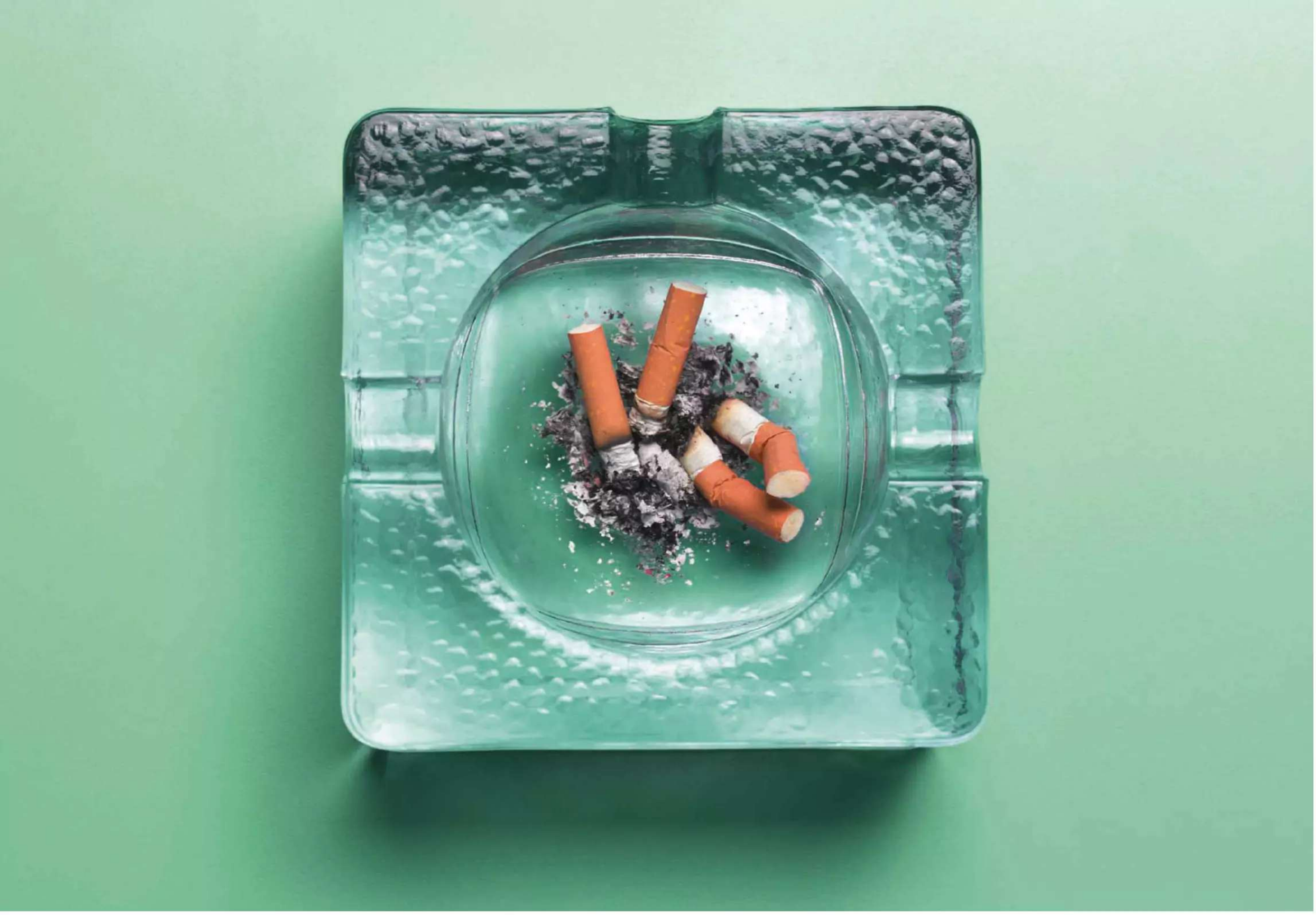
by **DR HELEN PILCHER**

Helen is a science writer with a PhD in cell biology.



ANALYSIS

Is smoking or vaping worse for you? It depends who's asking

Research suggests vaping is one of the best ways to help smokers quit the habit. But that doesn't mean it's a harmless alternative to smoking

ABOVE Research suggests that switching to vaping is a more effective method of giving up smoking than other nicotine replacement products

Smokers are increasingly unconvinced of the benefits of switching to e-cigarettes, or 'vaping' – using an electronic device to heat a liquid that contains nicotine and inhaling the vapour (as opposed to breathing in the smoke from burning tobacco). Last year, over a third of smokers surveyed in England thought vaping would be more harmful to their health than smoking – up from 12 per cent four years earlier – while another third thought vaping would be just as bad.

This is despite scientific evidence from the National Institute for Health and Care Excellence (NICE) showing the effects of smoking on our health, and a Cochrane review from 2022 that suggests vaping helps more people to quit than other nicotine replacement products. So, the perception of vaping is important because, as scientists established this year, smokers who think vaping is less harmful are more likely to switch.

While there are known health impacts of both vaping and smoking, many experts agree that vaping reduces harm compared to smoking. According to the National Health Service, for example, vaping exposes people to fewer toxins, and at lower levels, than smoking.

"It's not that we think e-cigarettes are totally safe, but smoking is uniquely deadly and kills one in two regular users," says Dr Jamie Hartmann-Boyce, whose work in health policy at the University of Massachusetts Amherst, in the US, focuses on tobacco control and e-cigarettes. "So, when we're comparing most things to smoking, most things come out looking better."

From the public's perspective, however, the picture is complicated by media reports sensationalising the harms of vaping while failing to emphasise everything we already know is harmful about smoking. Why? Probably because the health risks associated with smoking are old news and tend to affect older people, suggests Dr Sarah →

→ Jackson, a principal research fellow in University College London's Alcohol and Tobacco Research Group.

"I think if smoking was killing lots of young people, it would be all over the news," she says, "Obviously, it's not good news that there are young people vaping, but I do think that attracts the attention."

HEALTH RISKS

While it might be old news, it bears repeating that smoking is a risk factor for cancer, heart disease, infertility and problems in pregnancy, as well as a host of other health issues, and kills over eight million people every year. Scientists may not have done as much research on vaping, but burning tobacco in cigarette form produces a greater mix of toxic substances compared to heating the nicotine-containing liquid in a vape.

According to Jackson, then, we should be "quite confident" that vaping is less harmful than smoking and while she admits that more long-term studies are due, we shouldn't be under any illusions about the results.

"There may be long-term risks that we don't know about and people think that means they could potentially be as bad as [the risks] for smoking. But all the evidence we have points towards that being incredibly unlikely."

It's the longer-term effects that Dr Maxime Boidin, a senior lecturer in cardiac rehabilitation at Manchester Metropolitan University has been researching. Although, as a cardiac specialist, his study looks specifically at damage to blood vessels relevant to heart disease risk – not the overall health effects.

As Boidin explains, some studies already suggest that vaping reduces the influence of signalling molecules (nitric oxide) needed to keep blood vessels relaxed and healthy, as does smoking. "What we don't know is, if that mechanism happens, what happens to the blood vessel?" he says. "I'm trying to answer this question."

Boidin's study, which was due to be finished at the end of March, uses a clinically validated measure of how much blood vessels can expand to assess damage in people who have vaped for three to five years, compared to people who have smoked traditional tobacco products for a similar period.

Once completed, the study will go through the normal process of peer review before being published in a scientific journal. Results being reported in the media before this process is complete (as was the case with Boidin's study) can be a source of frustration for experts who are unable to judge the quality of the research or comment on the end results without a published paper.

Even when the study is published, it'll only tell us about the effects of vaping on the cardiovascular system, not, notes Boidin, any of the other aspects addressed in some press articles. "I'm not talking about the brain or the lungs," he says.

Media articles reporting on Boidin's study did, though, lead to discussions about how scientists can carry out fair trials comparing vaping with smoking.

ABOVE Vaping exposes users to fewer toxins than smoking tobacco

RIGHT The health risks associated with smoking must be clearly displayed on the packaging of tobacco products sold in the UK

"The number of people who vape without ever having smoked previously has grown rapidly since 2020"

SHUTTERSTOCK, GETTY IMAGES

An ideal study would be one where healthy people who have never smoked or vaped before were assigned to smoking or vaping groups and then monitored over a number of years.

This type of trial is, obviously, an ethical impossibility considering the harms, so scientists have instead looked at what changes when smokers switch to vaping.

"The evidence is really clear there. Those who do, reduce their health risks and that tells us that vaping, for those people, is likely to be substantially less harmful than smoking," says Hartmann-Boyce.

Another option is to do a study more like Boidin's, where scientists take measurements from people who have already chosen to vape or smoke. The difficulty here is ensuring that the vaping and smoking groups match in every respect so that factors like fitness, age or income level don't influence the results. What's more, vapers tend to be previous smokers so it can be hard to rule out historic damage caused by smoking.

NON-SMOKERS TURNED VAPERS

Hartmann-Boyce is the lead author of the previously mentioned Cochrane review, which is regularly updated with new evidence from trials of e-cigarettes for helping people quit smoking. The review shows that, in trials, e-cigarettes are more helpful than other nicotine replacements such as patches or gums.

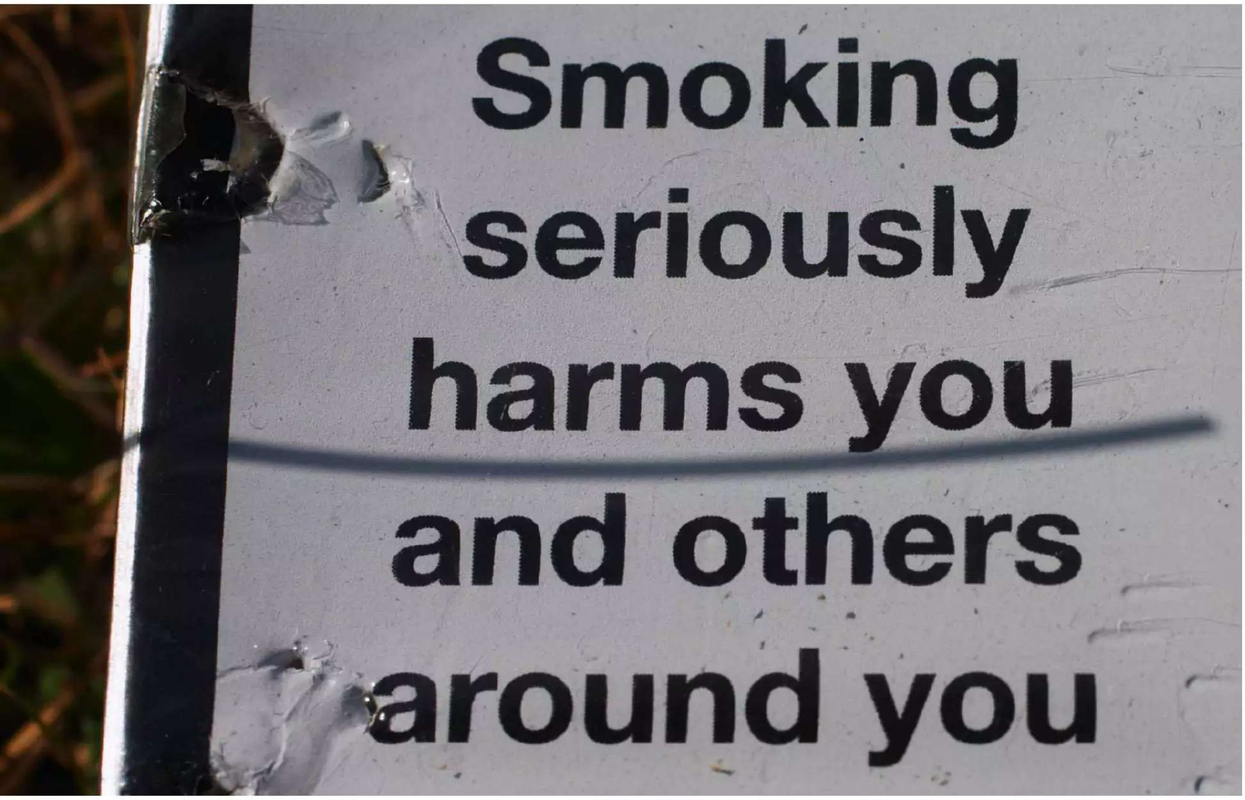
Jackson's recent work, meanwhile, backs up this finding with evidence from the real world, while showing that vaping is also now the most common method people use to quit smoking – used in about 40 per cent of attempts to quit in England.

When we consider people who have never smoked, however, vaping does pose more of a concern. The number of people who vape without having smoked previously has grown rapidly since 2020 – increasing seven-fold in England to exceed a million by April 2024. And as all our experts agreed, the health effects associated with vaping can't be zero.

"You're inhaling a host of chemicals that aren't clean air into your lungs," says Hartmann-Boyce, noting that we also need to consider the impacts of nicotine addiction. Whether vaping is more addictive has also been widely debated.

So, should the public message be: if you have to choose, choose vaping?

"Exactly that," Jackson agrees. "If the choice is between vaping and fresh air, choose fresh air. But if the choice is between vaping and smoking then yes, every day of the week, choose vaping." **SF**



by **HAYLEY BENNETT**

Hayley is a freelance science writer, based in Bristol, UK.

Aaand breathe...

Can a magnetic nasal strip open your airways, improve your breathing and stop you snoring?

"You've always made a lot of noise in your sleep," my adoring wife tells me as we get ready for bed. "That's why I have to wear these."

Over on her side of the bed, she's fitting industrial-grade plugs into her ears. On mine, I'm placing a magnetic strip over the bridge of my nose to see if it'll help with the decibel levels. I'm a snorer (or so she tells me). The reason I'm fixing magnets to my face is, hopefully, to do something about it and improve my sleep and hers.

The strip is called Airo and costs £60. It's a curved piece of hard plastic with magnets on both ends. These attach to smaller magnets that I've just stuck to my face, one on either side of my nose, just above the nostrils. As they clip together, the magnets lift my nostrils slightly. It feels weird, but not in a bad way. It's like my airways have been opened up, mechanically, to make it easier to breathe.

THE PROBLEM'S UNDER YOUR NOSE

Why might I need such a device? Well, one of the charming physical quirks I was born with is a deviated septum. It's probably the reason my wife resorts to expensive ear defenders to help her sleep. A deviated septum (which as many as 70 per cent of people have) is linked to snoring, sleep apnea, breathing problems and disordered smell.

If I shove a finger up my nose (strictly in the name of science) I can feel it – the left nostril is a lot more roomy than the right. And the tissue that separates them (my aforementioned crooked septum) doesn't run vertically towards a centre spot between my eyebrows – it leans to one side. Made of bone and cartilage, this wonky wall is the reason I snore and breathe through my mouth. The deviated septum obstructs my airways, meaning when I take a breath through my nose, it never feels like I'm getting enough oxygen.

"IF YOU BREATHE THROUGH YOUR NOSE AT NIGHT, THEN IN THEORY, YOU SHOULDN'T SNORE"

I hate running because my breathing always feels more laboured than it should. At night, as well as snoring, I take irregular gulps of air during sleep, presumably while wearing the expression of a startled goldfish. If all that wasn't enough, I also experience a kind of night terror, or sleep paralysis, where I jerk awake after having felt unable to move or breathe.

"Patients with a deviated septum can suffer in many ways," says Prof Peter Andrews, president of the British Rhinological Society. "Typically, they end up mouth breathing, which can have adverse effects on lung function."

It's optimal to breathe through the nose, Andrews tells me. "It's essentially an air-conditioning device, designed to filter the air so that when it reaches the lungs, it's perfect for oxygenation. If your nose is blocked, then you're not breathing as efficiently."

When your nasal passage is open though, these are non-issues. "If you breathe through your nose at night, then in theory, you shouldn't snore," Andrews says.

Airo claims to improve both your breathing and your sleep. The company says it reduces snoring in 'real time', doubling your nasal airflow and giving you as much as an hour extra sleep every night.

BREATHING EASY?

The first night I wear the Airo strip it goes remarkably well. Considering it's attached to my face, it doesn't bother me or prevent me from dropping off at all. It's comfortable. And the next morning, my wife – who has foregone the use of her ear plugs for the sake of this trial – is in shock.

"I don't think you made a sound," she tells me, shaking her head in disbelief.

The next night doesn't go so well. I have a night terror shortly after losing consciousness and the next morning, one of my beloved's eyebrows is raised. "It didn't work last night," she says. "Not at all."

For my part, I haven't noticed much difference in my sleep, for better or worse. And when I check data from the Apple Watch I've been wearing to bed, it confirms that there's no difference in my overall sleep duration. With or without the Airo strips, I'm getting a little under six hours a night. No wonder I'm tired.

What's more interesting is the data the watch has tracked about the different stages of my sleep. The Apple Watch is not a lab-grade sleep tracker. Nevertheless, it estimates that although there's little difference in my overall sleep time, I'm getting 30 minutes more REM sleep and 20 minutes more deep sleep when I'm wearing the Airo. I also spend a little less time awake during the night.

During the day, I try them out for exercise, wearing them to the gym and for a run. Again, they're comfortable and I can feel a difference in the air I'm taking in. Whether it adds up to a better workout, though, I'm not sure.

On the run, the adhesive slips as I begin to sweat and the Airo starts jiggling over the bridge of my nose. Eventually I remove it, before it falls off, but up until that point it had felt like I was breathing easier.

"Nasal strips certainly play a role in opening up the airway," Andrews says. Airo's magnetic strips are just one style. Adhesive strips that sit over the nose do a similar job, while other sleep aids are designed to fit inside the nostrils pushing the airway open. Studies suggest that they can help improve snoring, but results on overall sleep metrics are mixed.

My wife isn't a sleep scientist, but even with the mixed results, she's keen on a longer-term trial.

CASE FILE

SUBJECT
43-YEAR-OLD MALE, SNORER

ABSTRACT
Can a magnetic nasal strip improve sleep and cure night terrors?

TESTS
Quantitative sleep data tracked with an Apple Watch. Qualitative sleep data tracked by spouse.

RESULTS
No difference in overall sleep duration, but improvements in REM and deep sleep. Mixed results in bed-sharer satisfaction.

by **IAN TAYLOR**

Ian is a freelance science writer and the former deputy editor of BBC Science Focus.

Level up your desk

With just under half of us still working from home, to one degree or another, here's our pick of the products that can help improve your health and power up your productivity

by DANIEL BENNETT

Sit happens

Sitting is a dangerous business. As a pro-sitter myself, I've been benched by three office-chair related injuries in my career, including tennis elbow, which at the time seemed particularly cruel since I'd never set foot on a tennis court. The point is, I've now been injury-free since I bought a Herman Miller Aeron (with my own money). The key to its comfort is the 'Pellicle': the thin mesh across the chair that cradles you as though you're being held aloft by a sports massage therapist named Sven.

Aeron Office Chair
£1,372, ukstore.hermanmiller.com

I'm all ears

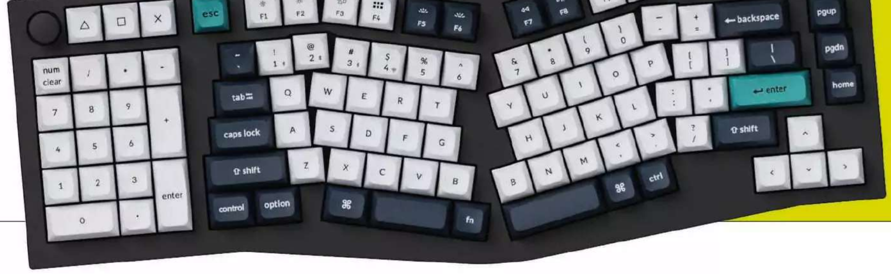
Desktop speakers give your ears a rest from headphones and, around these parts, loud music kickstarts Happy Hour (between 5 and 6pm if you're coming over). If you're looking to invest in something that sounds and looks great, and will last, it's hard to look past the Debut ConneX from German audiophile brand ELAC. They have ports for everything you might want to plug into them, but also work wirelessly via Bluetooth.

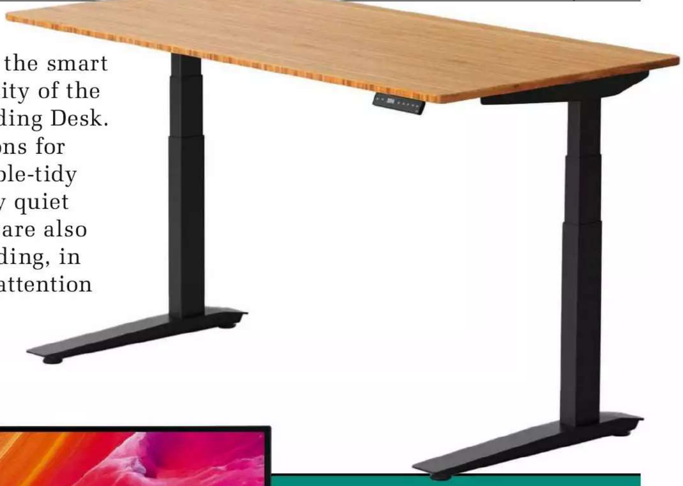
ELAC Debut ConneX Adsum
£529, elac.com

Marginal gains

In the world of mechanical keyboards, Keychron is both gateway drug and taboo, since it arrives pre-assembled. As someone who makes his living writing on a keyboard, I was on the fence, until I saw the Q14 Max, with the numpad on the left. Yes, the 'Southpaw' layout could help lefties with number input, but for me, the extra space means I'm less likely to lean over to one side and strain my wrist. No, I'm not made of glass, why do you ask?

Keychron Q14 Max,
$249.99 (approx £195),
keychron.com





There are levels to this

No seriously, sitting down really is dangerous… It can contribute to early-onset diabetes, certain forms of cancer and even "early death" according to the NHS's review of the data. Regular breaks and strolls around the house should spare you from the worst consequences, but I'm not taking any chances. There are plenty of standing desk options out there, from risers that sit on your desk to laptop stands that are several feet tall, but I like the smart simplicity and sustainability of the Fully Jarvis Bamboo Standing Desk. It has programmable options for the desk's height, good cable-tidy options and it's reasonably quiet to operate. Recent studies are also starting to show that standing, in bursts, can improve your attention and focus at work.

Fully Jarvis Standing Desk,
£760, ukstore.hermanmiller.com

ASUS ProArt

Chat routine

Are you even working if you haven't got an AI language model helping you out? While I've yet to be convinced by ChatGPT et al's writing skills, I do find it useful when it comes to tasks like building data sets, writing automation code and even carrying out initial research. That's why my next desk upgrade is almost certainly going to be a second monitor for a virtual assistant to live on. This ProArt model pretty much does everything very well at a reasonable price. (In fact, it should really be your first monitor). It's sharp, bright and accurate since it's designed for creative professionals. It has a 27in (69cm) display and ports to let you transfer files or daisy chain it to additional screens. Its ergonomic stand also means you can rotate it to portrait mode, which makes it the ideal real estate to house an AI assistant.

ASUS ProArt Display PA279CRV
£469, asus.com

Shelf appeal

Most monitors – and the stands they come with – fall annoyingly short of eye level, which is a common cause of neck strain and backache. One option is a monitor arm, although it can be an eyesore and, take it from me, a pain to install. The other is a desktop shelf that elevates your monitor to a more comfortable height and delivers some desk real estate. This is the money-no-object option: a monitor stand that doubles as your cable management and dock (providing extra USB ports) to hook up to your workstation. It has adjustable feet too, and even a wireless charging module for your phone. Best of all, there's eight plug sockets on the back, so you can just send one power wire to your desk, and plug everything else into the Hexcal Studio.

Hexcal Studio
$899 (approx £695), hexcal.com

Sweet bliss

If you're in the Apple ecosystem, then a pair of AirPods Pro 2 is almost essential for a productive work life. They're as good at silencing the aural assault of a busy flight as they are at muting that spluttering, hacking colleague two desks over. Plus, transparency mode is helpful since it turns down noise-cancelling and audio volume when the AirPods sense someone talking to you (although it also activates if you sing to yourself, which is sub-optimal). The AirPods' most useful trick is the way they flick seamlessly between your Apple devices' Bluetooth connections with one button press. Plus there's the adaptive equalisers, spatial audio and even the option to turn them into hearing aids. Oh, and they sound great too.

AirPods Pro 2
£229, apple.com/uk

IDEAS WE LIKE...

Our pick of the month's smartest tech

...A GO-ANYWHERE SPEAKER

Turtlebox's rugged new Ranger speaker is built for people who want to listen to music without headphones, wherever they are and whatever they're doing. It's a heavy-duty, portable speaker that's built to go anywhere and be treated badly. It's drop-, crush- and dust-proof, and, with its IP-67 rating, is capable of surviving a dip in the sea. Unlike Turtlebox's other speakers, though, it isn't buoyant. It won't float, in other words. So if you do take it near water that's deeper than 1m (3ft), be sure to keep a firm grip on its carry handle.

Turtlebox Ranger
$220 (approx £170), turtleboxaudio.com

TURTLEBOX
TURTLEBOX

↑...A NEW 'BUDGET' IPHONE

As phone prices continue to soar, the demand for more affordable, mid-range devices is growing louder. The new iPhone 16e is Apple's attempt to meet that demand. It's much cheaper than most manufacturers' flagship models, but, at £599, it's not exactly cheap. Naturally, it doesn't have the same bells and whistles as its bigger brother, the iPhone 16 Pro (£999), but does feature the USB-C charge port and action button (introduced on the iPhone 15), a fantastic camera, better battery and Apple's A18 chip for faster processing and AI support.

iPhone 16e
£599, apple.com

↓... A HEAD TORCH THAT STAYS ON YOUR HEAD

The problem with most head torches is that they don't always stay on your head, especially if you're bouncing around a lot, like you would if you were running after dark. BioLite has tried to fix that with its new 78g (2.7oz) Dash 450. By integrating the electric parts into the band and balancing them between the front and back, it should remain on your head no matter how rugged the route gets. It's said to illuminate up to 90m (almost 300ft) of the path ahead and, thanks to its red rear light, will alert anyone approaching from behind to your presence.

Biolite Dash 450
$59.95 (approx £45), bioliteenergy.com

↑...A HIGH-PERFORMANCE SET OF HEADPHONES

Audio-Technica's headphones are popular with musicians and audiophiles, but they're often pricey. The Japanese company aims to change that with its new ATH-R30x headphones. The big difference between these and 'regular' headphones is that they're open-backed. Regular headphones trap the sound in, which can create unwanted noise. Opening the backs releases it so you get the clearest, most accurate version of whatever it is you're listening to. Great at home or in the studio; not so good on public transport.

Audio-Technica ATH-R30x
$99 (approx £75), audio-technica.com

↓...A HOME STUDIO SET-UP

Onkyo says its newest speakers are designed for 'creators'. They're intended for home studio set-ups where budgets are, obviously, somewhat tighter, but great audio is nevertheless required for whatever content is being created – whether it needs a musical soundtrack or a spoken-word voiceover. Based on the specs, they're versatile speakers that'll meet the needs of just about anyone. They come in various designs to suit whatever décor scheme your home studio has and the expected sub-$300 price tag makes them relatively affordable.

Onkyo Creator Series
£TBC, Onkyo.com

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IDEAS WE DON'T LIKE...

... A FLYING CAR

Tech companies are still chasing the dream of flying cars. And while most look like drones carrying a passenger cabin, the one from Alef does at least resemble a regular car... albeit one with Batmobile styling and what looks like a wire-mesh body. Details are sparse for now, but you can pre-order it for as little as $150 (the final cost is projected to be $300,000). Its eventual incarnation is expected to be roadworthy and capable of beating the traffic by flying over it. But as it stands, waxing that body will be a nightmare.

Alef Aero,
$299,999 (approx £231,000),
alef.aero

... A CONVERSATION-PIECE KEYBOARD

Never before has a product's name been so apt. This is the Icebreaker, a keyboard crafted from a single piece of aluminium. It's bigger and better looking (if you're a Bond villain with a penchant for heavy metal aesthetics) than most keyboards. It's also a lot more expensive – the Icebreaker will set you back a cool $1,600. It will, however, most definitely be a conversation starter for anyone who sees it sitting on your desk. Although, we're guessing most of those conversations will start with: "Blimey, how much did that thing cost?!"

The Icebreaker
$1,600 (approx £1,230),
serene.industries

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THE BLUEPRINT FOR TRUE RESILIENCE

Psychologists are now finding that mental flexibility, not pushing through at all costs, is the real key to perseverance

by KELLY OAKES

ST·HELENS
SUTTON
A·C·
270
STEVEN
308
ADAM
280

When the road gets tough, do you dig deep, push forward and refuse to back down? If so, you likely believe in the power of mental toughness – the ability to overcome obstacles with sheer focus and will.

The idea is simple enough: by strengthening your mind, you can bulldoze through any barrier standing between you and your goals, whether it's crushing a personal best at the gym or landing that big promotion. Mental toughness is about believing in your ability to persevere, no matter what stands in your way.

Sounds logical, even admirable, right? But there's a huge hidden catch: relying solely on mental toughness might not serve you well in the long run.

Take marathon running as an example. If someone adopted a mindset of mental toughness, they could end up powering through their pain – but only once.

"They might finish their race through this idea of mental toughness," says Dr Josephine Perry, a chartered sports and exercise psychologist. "But they might never be able to run another one, because they've hurt themselves so much along the way. They've just totally fallen out of love with the process, because it was all about pain and discomfort."

You'll be pleased to hear there's another way. It's called a 'flexible mindset'. You'll certainly still encounter setbacks, but instead of blindly pushing through, you might rethink your training plan, while still keeping your goals in mind. It's about being strategic, stepping back and considering the long-term impact of your actions. "Flexibility is about winning the war and being more clever with how you do things… rather than just getting your head down and throwing yourself into every battle that comes along," says Perry.

Mental flexibility isn't just for athletes, though. Research shows that those who develop it reap significant mental and professional benefits. In one large analysis of multiple studies using

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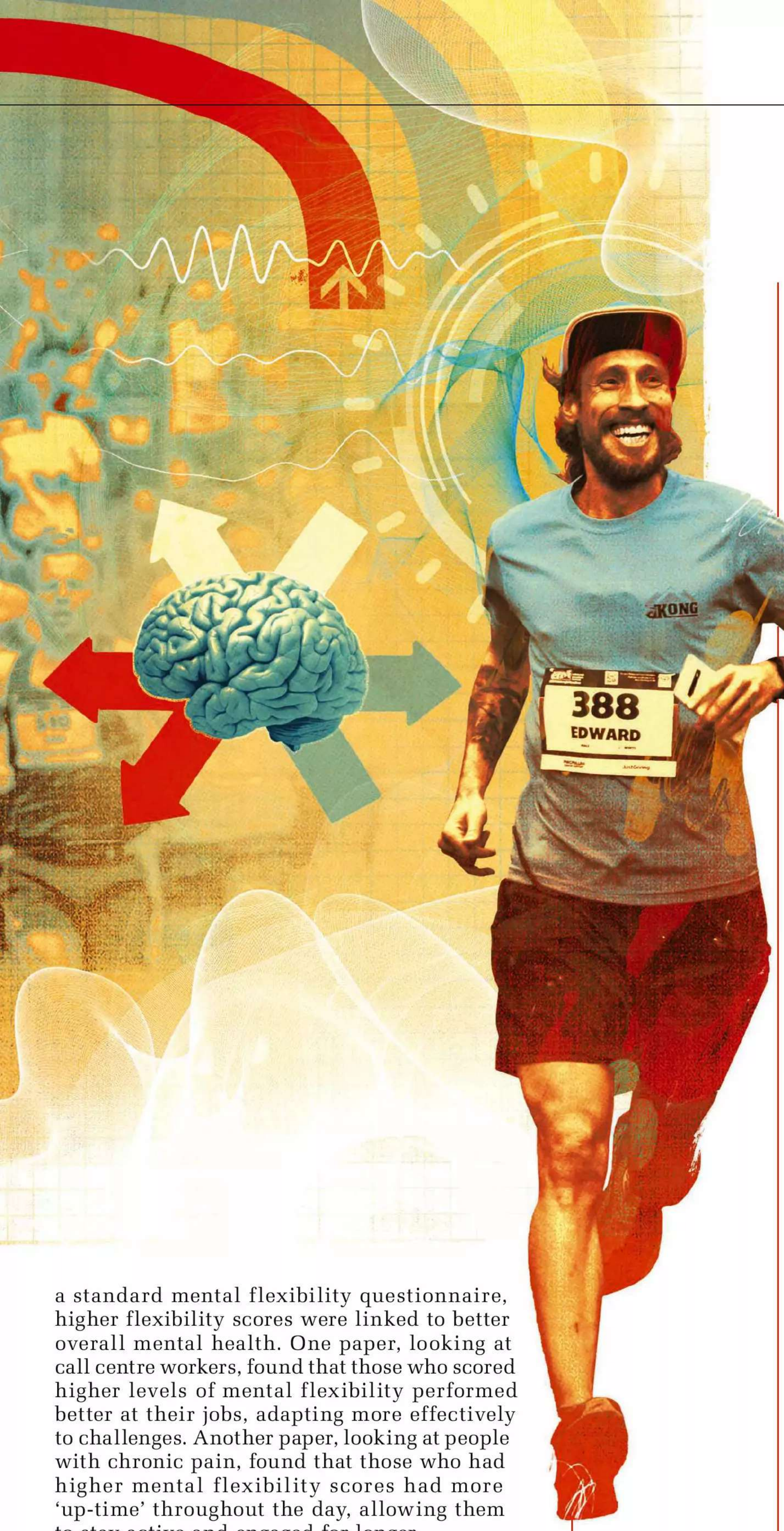


a standard mental flexibility questionnaire, higher flexibility scores were linked to better overall mental health. One paper, looking at call centre workers, found that those who scored higher levels of mental flexibility performed better at their jobs, adapting more effectively to challenges. Another paper, looking at people with chronic pain, found that those who had higher mental flexibility scores had more 'up-time' throughout the day, allowing them to stay active and engaged for longer.

The list goes on: according to one study, US military veterans who were more mentally flexible exhibited fewer signs of post-traumatic stress disorder (PTSD). Another paper, looking at wellbeing in the UK, found that people who were more mentally flexible were less likely to experience anxiety and depression during the COVID-19 pandemic.

Even more compelling, some psychologists contend that mental flexibility not only trumps sheer toughness, it may also outperform what we call positive thinking. In this clinical sense, positive thinking involves maintaining an unwavering, optimistic outlook, even when it drifts away from reality.

"People are still talking about being optimistic, [having] gratitude, being kind, being generous," says Dr Todd Kashdan, a professor of psychology and founder of the Well-Being Lab at George Mason University, in the US. "All those things are good, but certain situations require a little bit more darkness, a little bit more negativity."

BEND, DON'T BREAK

So, what exactly is mental flexibility, also known as psychological flexibility? One definition Kashdan works with is a willingness to match your behaviour to whatever the situation demands.

Say, for example, you're trying to persuade your colleagues to get behind your idea before a big meeting, or convince your surly teenager to get an early night for once. Someone who is mentally flexible will be able to change their approach in response to the feedback they're getting. "[They might think] 'Okay, humour isn't working here… Let me try listening and asking open-ended questions'," says Kashdan. "You're able to pivot much easier when you have other strategies that are easy to deploy and access."

The idea of mental flexibility draws on the principles of Acceptance and Commitment Therapy (ACT), an approach to psychotherapy that focuses on – as the name suggests – accepting your feelings as they are, including any that are painful or difficult, and committing to making meaningful changes in your life.

Acceptance is a crucial part of mental flexibility because, however much we might try, we can't avoid negative feelings. "If you want to excel in fitness, you're going to have a lot of negative emotions as you grunt through days where you don't want to wake up," says Kashdan. "If you want to be a master in psychology or business or politics, that level of learning requires a lot of confusion, difficulty and self-doubt."

While accepting those negative thoughts might seem counterproductive, research shows that the alternative – trying to suppress them – simply →

Train your mind to be more flexible

A key part of mental flexibility is handling tough emotions. Here's how to spot difficult thoughts that might trip you up, and how to plan for future obstacles…

Find your triggers

It's helpful to identify your 'emotional prejudice profile'. This involves figuring out your attitude towards different emotions – your so-called 'meta emotions'.

They could be anything, but as a starting point, think about: sadness, anger, fear, embarrassment, guilt, shame and boredom. Do any trigger a particularly strong reaction? Do you find it easy to get angry, or maybe you find embarrassment intolerable?

Another approach is to reflect on the last time you experienced these emotions. Which felt the worst, lingered the longest or was hardest to shake off? Recognising these patterns is the first step toward building emotional flexibility.

"You need to know which [emotions] have their fishhooks in you, that suck you out of the present moment," says Kashdan. These will be your potential stumbling blocks on the path to mental flexibility. Pay close attention when you notice them pop up.

Reframing

The next step is identifying your initial reaction to a particular thought or feeling, and finding a course of action that better serves you – both now and over the long-term.

One way to reframe your thoughts is to think about the advice you would give to a friend who was having the same thoughts. "We're really good at giving other people advice and giving other people support when they feel negative emotions," says Kashdan. "But for us, we're like, 'Suck it up! You can handle it – it's no big deal'." Treat yourself as you would someone you really care about.

Another way is to think about how your future self would feel about your actions today. Say you disagreed with someone in a work meeting, for example – would your future self prefer that you kept the peace, or spoke out? Playing with time in this way could help you to figure out if peacekeeping is really what you want to do in that situation, or if it's simply a way to avoid conflict and the negative emotions that come along with it.

"What we do today creates and informs who we're going to be in the future," says Kashdan.

GETTY IMAGES ILLUSTRATION: ANDY POTTS

"THE GOAL ISN'T TO RIDICULE YOURSELF, BUT TO STOP TREATING YOUR THOUGHTS AS GOSPEL AND GET CURIOUS"

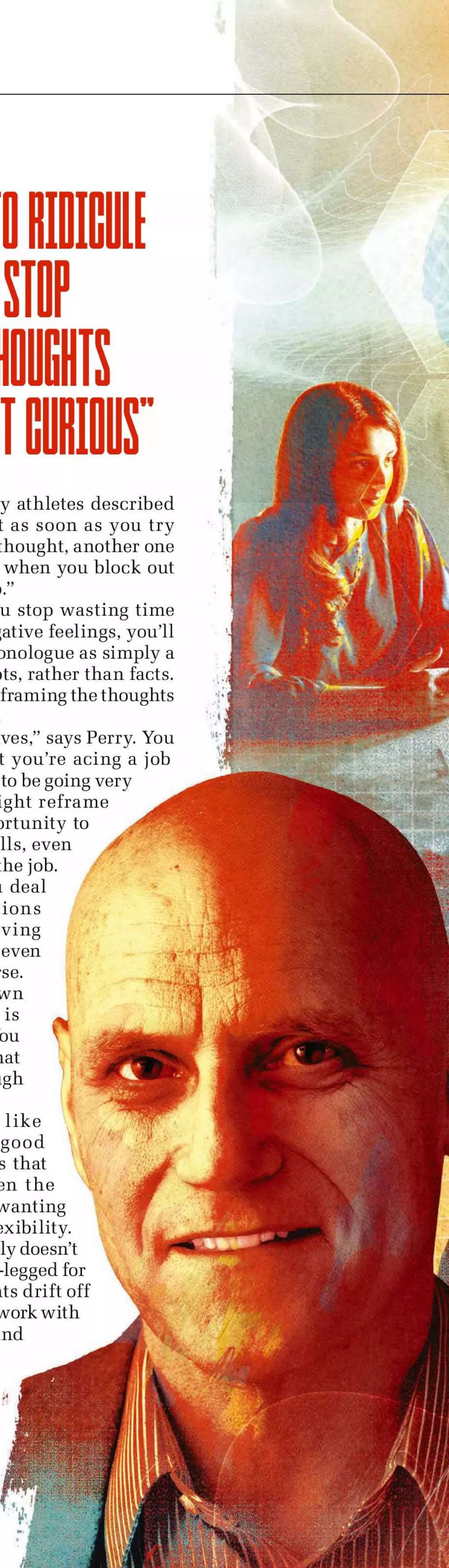
→ doesn't work. "One of my athletes described it as 'whack-a-mole' – that as soon as you try and block out one negative thought, another one pops up," says Perry. "And when you block out that one, another shows up."

The idea is that, once you stop wasting time struggling against your negative feelings, you'll be able to see your inner monologue as simply a string of thoughts or prompts, rather than facts. From there, you can begin reframing the thoughts that don't serve your goals.

"We're not lying to ourselves," says Perry. You wouldn't tell yourself that you're acing a job interview that doesn't seem to be going very well, for example. You might reframe it, however, as a good opportunity to practise your interview skills, even if you don't end up getting the job. This framing can help you deal with any difficult situations at hand and keep you moving towards your ultimate goal, even when reality veers off course.

Starting to train your own brain to be more flexible is relatively simple, on paper. You just need to start noticing what thoughts are running through your mind.

If this sounds a lot like mindfulness, there's a good reason for that – Perry says that mindfulness work is often the starting point for athletes wanting to improve their mental flexibility. But – thankfully – it absolutely doesn't have to involve sitting cross-legged for half an hour as your thoughts drift off on imaginary clouds. In her work with athletes, Perry says she's found that activities, such as swimming, yoga or even playing with



jigsaws, serve as a good environment to start practising this vital skill.

Think about activities you already do where you can allow your mind to wander. It could be going for a walk, pottering around the garden or even folding laundry. “We want you doing some kind of activity that you get some enjoyment out of, but that isn’t putting you in any sort of threatening environment,” says Perry.

MIND OVER CHATTER

Once you’ve started to pay attention to your inner monologue, the next step is to create distance between you and your thoughts, something psychologists call cognitive defusion.

There are lots of different ways you can do this. One is to buffer the thought with extra words. If you’re thinking ‘I’m too slow’ try rewording it as ‘I’m thinking that I’m too slow’. Or go one step further: ‘I’m noticing that I’m thinking that I’m too slow’.

Dr Steven Hayes, the psychologist who originally developed ACT, even suggests giving your mind a name for some additional distance. Another option is to sing the thought out loud. Or you can distil it down to one word and repeat it out loud, fast, for 30 seconds, until the word loses its meaning.

The goal isn’t to ridicule yourself, but to stop treating your thoughts as gospel and get →

→ curious. “We want to be more conscious of asking is this a thought or is it a fact?” says Perry. “Most of the time, without doing this work, we believe everything is a fact.”

You might start to notice patterns or types of self-talk that keep cropping up. A common one, says Perry, is telling yourself you ‘should’ be able to do something. The word is loaded with expectations and pressure, and puts you in a lose-lose situation.

“If you [do the thing you feel you should be doing], it’s because you expected to, but if you don’t, you’ve definitely failed,” she says. “There’s constantly this gap between where you are and where you think you should be, and that’s where you beat yourself up.”

“‘Should’ is a word we’re really trying to catch when we’re trying to notice our thoughts,” says Perry. Instead, she suggests consciously reframing ‘I should’ thoughts to ‘I’m working towards’, or ‘I would like to’ thoughts.

When you reach a point where you notice your thoughts without getting caught up in them, you have an opportunity to think more clearly and respond to your circumstances with actions that better align with your values.

But what if your values aren’t something you’ve ever consciously thought about? Well, the experts say it’s time to start. One way is to begin with a long list of options and cross out the ones you don’t care that much about, until you’ve whittled it down. (You can find lists specifically for this exercise online – simply search the term ‘list of values’.)

“It’s really hard, because most things on the sheet will be good things to do, but we’re trying to get to what’s genuinely at the core of who we are,” she says. “When you’ve got down to about 10 or 12, you’ll start to notice some themes showing up.” Ideally, you want to end up with just three values.

You can test your shortlist by thinking about how you’d react in a situation when someone violates one of them. “For instance, at my local Parkrun there’s a guy who cheats and cuts the corners,” says Perry. “I can laugh about it, but I have a friend that I run with, and [it] infuriates them. It really annoys them. And I imagine that’s because they’ve got a value of fairness and justice.”

Another way to clarify your values is to put them in competition with each other. For example, what’s most important to you: creativity or generosity?

“Don’t judge what you lean towards, because this is who you are,” says Kashdan. “If you walk through the world trying to be the Dalai Lama when you want to be Jim Morrison, you’re not going to live the one life that you have a chance for.”

YOUR BRAIN, THE SWISS ARMY KNIFE

Ultimately, mental flexibility is about ditching your inner drill sergeant and finding a bit more compassion for yourself. Once you understand what really makes you tick, you can work with your brain instead of against it.

“MENTAL FLEXIBILITY IS ABOUT DITCHING YOUR INNER DRILL SERGEANT AND FINDING MORE COMPASSION FOR YOURSELF”

GETTY IMAGES ILLUSTRATION: ANDY POTTS

In fact, there are some situations where you might want to go a step further than simple acceptance and choose to harness your negative emotions to propel you towards your goals. For example, research shows that anger can help you find the courage you need for an uncomfortable confrontation, while envy can motivate you to improve your performance and outperform others.

The possibility of harnessing negative emotions is one reason why Kashdan thinks mental flexibility has the edge over positive thinking. "We find that people who are able to do this better have a greater 'Swiss army knife' of coping strategies for dealing with stresses in everyday life," he says.

But when you get tempted to turn that negativity towards yourself, hit pause and find some self-compassion instead. This will save you from expending energy on wrestling with your negative thoughts, allowing you to channel that energy towards the things you value instead.

In fact, along with being something you can practise when your best-laid plans inevitably clash with reality, self-compassion could even change the way you think about your ambitions in the first place.

"When we're setting our goals… we so often look at our weaknesses and the things we need to fix or improve," says Perry. "But I would love to see more people focus on their strengths. Where are they already amazing? How can they do more of that?" **SF**

by **KELLY OAKES**
Kelly is a science writer who covers health, technology and the environment.

Bunker Mentality

A growing number of concerned citizens are building subterranean emergency bunkers as a precaution against disaster. Should you join the underground movement? And if so, how?

by IAN TAYLOR

In February 2025, scientists at the University of Chicago moved the Doomsday Clock to 89 seconds to midnight. The clock is a metaphor for humanity's risk of extinction and this is the closest it has ever been to 'boom-time'. But given the state of the world, who could blame the scientists for their horror-logical tinkering?

Climate scientists warn that we're behind targets to prevent catastrophic climate change. Artificial intelligence continues its march despite the omens of multiple experts and Hollywood movies. Even bird flu is attempting a comeback.

So it's perhaps no great surprise that an increasing number of people aren't hanging around to find out which aforementioned apocalypse strikes first. Concerned citizens and governments alike are investing in underground shelters, designed to sustain life in the event of a doomsday scenario.

Notable members of this underground movement include Facebook founder Mark Zuckerberg, who is reportedly building a vast shelter, with its own food and energy supplies, in a compound in Hawaii. Former Microsoft CEO Bill Gates is also reported to have huge shelters under his homes, in California and Washington.

But it's not just the super-rich who are bunker-curious. Nation states have also explored the idea. At the end of 2024, Switzerland announced plans to revamp its vast network of 360,000 underground shelters – enough to house more than 9 million people. (In Switzerland, every citizen has a right to underground shelter thanks to a law passed in 1963.)

Meanwhile, in Finland, the city of Helsinki is often hailed as the gold standard of underground civil defence planning, with huge spaces built not only for 'just-in-case' scenarios, but integrated into modern life with swimming pools and restaurants.

The UK has a number of Cold War-era bunkers, but experts agree that most of them are no longer fit for purpose. With no sign that the government is building new shelters, some people are working with specialist firms to construct their own liveable underground spaces.

"IT'S NOT JUST THE SUPER-RICH WHO ARE BUNKER-CURIOUS"

"Most of my business was panic rooms, safe rooms, security doors and windows to make a secure area inside the residence in case of home invasion. Now, I'd say it's 50/50 between that and underground shelters," says Paul Weldon, who runs The Panic Room Company.

He says the shift started with the onset of the Ukraine war, and that he now builds custom bunkers in the UK and abroad. But it's not just the ultra-wealthy who are doing it.

"It's come further down the food chain," Weldon says. "For example, we're getting enquiries from people who have already got a basement and they want to make it secure. Then you're talking £100,000 as opposed to half a million minimum for a bespoke underground bunker."

Weldon believes that a full-scale nuclear winter isn't the most realistic risk. Instead, he says most shelters are built as a shorter-term getaway in the event of floods, serious civil unrest or even a dirty bomb.

So, should you start digging out the garden? If so, how should you design your shelter? What should you stockpile? And how do you supply it with clean air, water and energy?

Fear not – or maybe a lot, if that's where your head's at – because we're digging deep into the subject, offering triple-reinforced tips on how to build your very own underground bunker. →

GETTY IMAGES, VIVOS SHELTERS

ENGINEERING

The average, 'garden-variety' bomb shelter isn't designed to withstand a direct hit. You'd have to be extremely unlucky for a warhead to land directly on top of you. "The idea of putting them underground is in case there's a blast a few miles away, as the energy released travels horizontally and will pass over the bunker," says Weldon.

For a family of five, he recommends a shelter that's around 8 x 4m (26 x 13ft). This would allow you to survive in some comfort with at least some individual privacy.

The majority of shelters are made from concrete. "You can use lead, but it's very expensive to do," Weldon says. "If you were building just an underground car park, for example, it's no different to that. The thicker the concrete, the greater the protection from blasts and radiation. For a NATO-grade shelter, it's probably 2–3m (6–9ft) concrete in width and a couple of metres of concrete on the top."

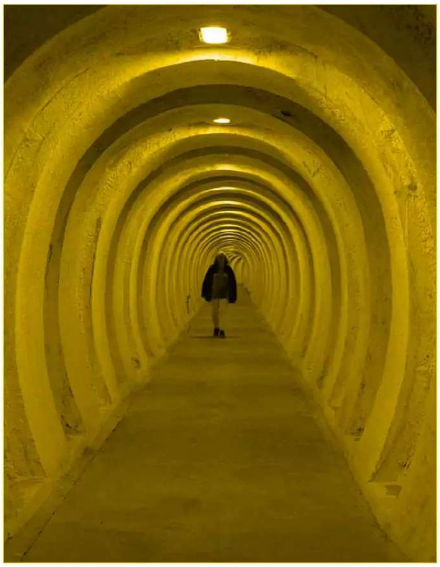
Scientists have run the numbers on what you would need for full-scale nuclear fallout. "In a worst-case scenario, the level of protection offered by radiation shielding materials, such as high-density concrete, is determined by their ability to attenuate both neutron and gamma radiation effectively," says Prof Patrick Tang at the University of Newcastle, Australia.

In 2024, Tang co-authored a review of radiation-shielding concrete. He recommends heavy concrete with a density greater than 3,200kg/m³ (200lb/ft³). This offers a 'dose transmission factor' that prevents radiation from fission bombs penetrating the shelter. "This level of thickness ensures that the dose behind the shield remains at or below 0.0001 sieverts [units of harmful radiation], which is considered safe for human exposure," he says.

You'll also want some blast doors. These can protect you from explosions and flooding.

"The door can be stepped into the concrete wall and you then pour concrete into the door itself," says Weldon. "Alternatively, you can use steel. The style we use is about 20mm (almost 1in) thick with a steel film that, again, is set into the concrete. That's the initial [door], but we double up."

It's the end of the world, after all – you can't be too careful.



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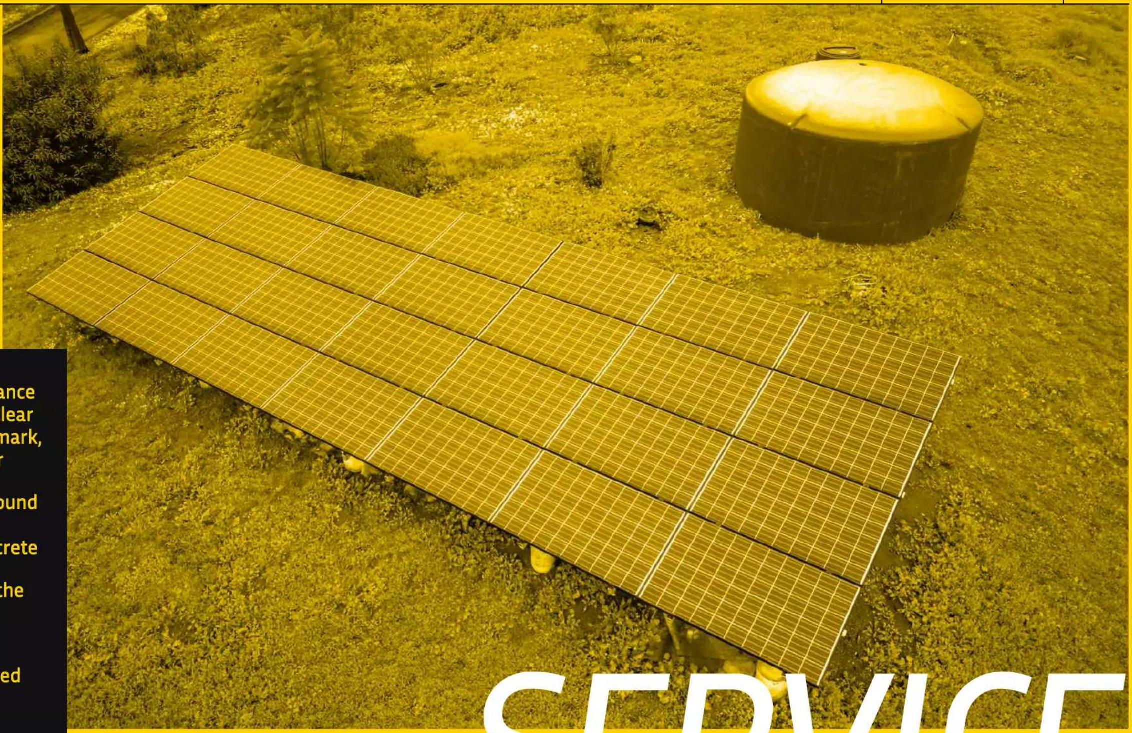


BELOW LEFT The entrance of the 'Reagan West' nuclear bunker in Skorping, Denmark, built during the Cold War

LEFT A private underground car park made from ultra-thick layers of concrete

RIGHT Solar panels on the surface could provide sustainable energy

BELOW A diesel-powered electricity generator

SERVICES

Clean air. Electricity. Ideally, Wi-Fi. These are some of the creature comforts we would put on our wishlist for a doomsday shelter. Most of them are fairly straightforward to install. Power can come from a mains link-up, backup generator or a self-sufficient energy source, such as surface-level solar panels.

If you want to speak to the outside world, Weldon says that internet and satellite phones are also fairly standard, with external aerials wired to the bunker. "More and more we also fit with Starlink," he says, referring to the massive satellite constellation that provides internet access almost anywhere in the world.

Ensuring fresh air in the sealed environment is also critical, says Antonia Cornaro of the International Tunnelling and Underground Space Association, based in Switzerland. "Many shelters use high-efficiency particulate air (HEPA) filters or overpressure systems to keep out contaminants."

HEPA filters are designed to keep out 99 per cent of particulate matter, while overpressure systems are standard for any structure designed to protect against chemical, biological, radiological and nuclear threats. It creates a safe area where the air pressure inside the bunker is higher than outside, stopping contaminated air from entering.

FOOD

In February 2025, the UK's National Preparedness Commission published a report called 'Just in Case', looking at the country's food resilience in case of emergencies. It's a sobering read. It concludes that "the UK now lacks a coherent food security and resilience strategy fit for… 21st-century geopolitics."

The report's author, Prof Timothy Lang, studied other countries' preparedness for so-called food shocks. "Switzerland stores three months of major commodities and a year ago they passed a regulation saying they're going to raise it to 12 months," he says. "Germany gives very detailed official advice, even for vegetarians and non-vegetarians and so on."

German authorities recommend that citizens stockpile 10 days' worth of food per person, based on 2,200 calories per day and offer detailed nutritional breakdowns. These include 3kg (6.5lbs) of grain products, bread and potatoes; 4kg (almost 9lbs) of vegetables; 2.5kg (5.5lbs) of fruit; and 1.2kg (2.5lbs) of meat, fish and eggs. For something more extreme, the Mormon Church advises its members to have a three-month stockpile.

In the UK, there's no such advice. So, what should you have in your store cupboard or bunker? The obvious examples are tinned goods – low-acid meat and vegetables, which can last five years or more.

"We have tins with a shelf life of 25 years," says Leigh Price, owner of survival and emergency supplies store The Bugout. "But realistically, if you store them correctly, they'll never go off."

Price also sells packs of freeze-dried foods, similar to the pouches stored on the International Space Station. "It's pre-cooked food – chilli con carne, for example – and it's freeze-dried to take out all the moisture." That way it can be stored long-term and heated safely.

For Price, who grew up in mid-Wales, storing food is natural. "I remember in 1982 when we had a blizzard, we were cut off for four days, but most people had a good pantry full of food and tins. Speak to farmers – they always need to make sure there's plenty of food in the house. It's just people have lost that way of living because [shopping] is so convenient now."

In 2023, a pair of supply chain researchers based at the University of Bradford argued that stockpiling a reasonable amount of food is something we should all start doing again. "Prepping – thinking ahead and being proactive – is the opposite of panic buying," they said.

ABOVE If stored correctly, tinned and freeze-dried food, can last almost indefinitely

"PREPPING – THINKING AHEAD AND BEING PROACTIVE – IS THE OPPOSITE OF PANIC BUYING"

ALAMY X2, GETTY IMAGES

WATER

Humans can live for around 30 days without food, but only three without water, so any underground shelter requires some liquid thinking. In the bunkers he builds, Weldon keeps things simple.

"We use the big water dispensers you see in offices for clean water, or larger containers that can be filled if it looks as though something's going to happen," he says. "In one installation, we had a very simple steel wash basin with two tanks underneath, one for fresh water and one for waste, all operated with a foot pump."

Drainage becomes important if you're underground for any length of time, so Weldon builds that into his designs, along with toilets that have special valves.

For larger-scale shelters or underground civil spaces, location is key. "If you can access groundwater or an aquifer, then you're able to bring in fresh water and discharge waste at scale," says Antonia. "And wells, of course, are possible."

But assuming you don't have a well in the garden, how much clean water should you stockpile? Fortunately, the World Health Organization has done the sums for us…

WATER USE	REQUIRED VOLUME (LITRES PER DAY)
DRINKING	2.5–3LPD
HYGIENE	2–6LPD
COOKING	3-6LPD

What's in your go-bag?

Everyone from the Red Cross to the British government recommends that you keep an emergency kit ready for just-in-case scenarios, such as floods, fires and power cuts. Your go-bag should contain items that'll keep you safe based on the likely risks in your area, says Price.

"It depends if you're in, say, a flood zone – what are the essentials you'd need? You're not talking about 9mm pistols and all that rubbish. It's just practical stuff. If you've got kids, you might want to take some colouring boxes and playing cards in case you have to vacate your house and go to the local sports hall, maybe overnight."

"Preppers get a bit of a reputation that they're all waiting for the end of the world. But it's not that; it's just being proactive and making sure you and your family are safe and as comfortable as possible if something happens."

Here's a starter kit, based on the combined advice of multiple government and charity sources:

- Bottled water (three gallons per person, ideally)
- Tinned meat, fruit and vegetables
- Other non-perishable meals (such as freeze-dried or dehydrated meals)
- Warm and waterproof clothing
- First aid kit and any regular medication
- Battery or wind-up torch
- Battery or wind-up radio
- Solar-powered batteries
- Multitool
- Hand sanitiser and/or wet wipes
- Baby supplies (such as nappies, formula) if required
- Local maps
- Lists of vital phone numbers and addresses

FIRST AID KIT

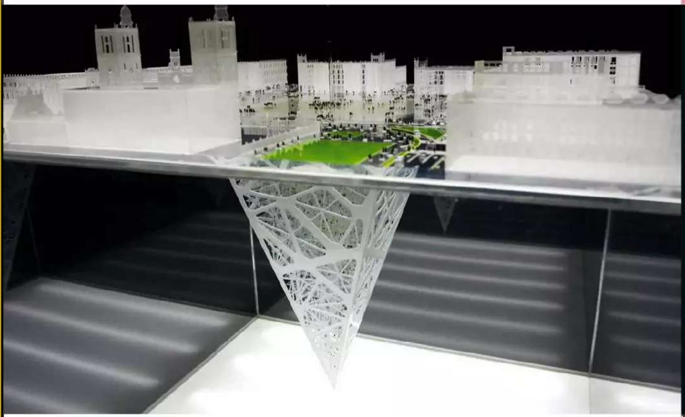
Is our future underground?

The underground isn't just for the 'End of Days'. Some civic planners and environmentalists believe the subsurface is an underused resource. So, what could we do down there?

by **IAN TAYLOR**
Ian is a freelance science writer and the former deputy editor of BBC Science Focus.

AGRICULTURE

Underground farming involves growing crops beneath Earth's surface in controlled environments, such as tunnels, basements and abandoned mines. It relies on artificial lighting, hydroponics and climate control to create optimal growing conditions without relying on sunlight or weather. Advocates, including the operators of a farm in the London Underground, argue that the method conserves water, reduces the need for pesticides and allows year-round production, while increasing food security in densely populated areas.



EARTHSCRAPERS

Imagine an inverted skyscraper that extends for storeys under your feet instead of over your head. Developers claim that building earthscrapers will save on steel costs, as well as on heating and cooling systems. Proposed examples include the earthquake-proof complex Underground Science City, planning to house 4,500 researchers in Singapore. In 2018, the InterContinental Shanghai Wonderland hotel was built into the side of an abandoned quarry outside Shanghai.

HYPERLOOP

One of Elon Musk's many projects, Hyperloop is said to be a high-speed, low-carbon underground transport system where passenger pods travel through low-pressure tubes that reduce air resistance and allow speeds of over 1,120km/h (700mph). The idea is that by using magnetic levitation and electric propulsion, it will reduce travel times between major cities. But the project still has many technical challenges to overcome before it can become a reality.

HYPERLOOP
TRANSPORTATION TECHNOLOGIES

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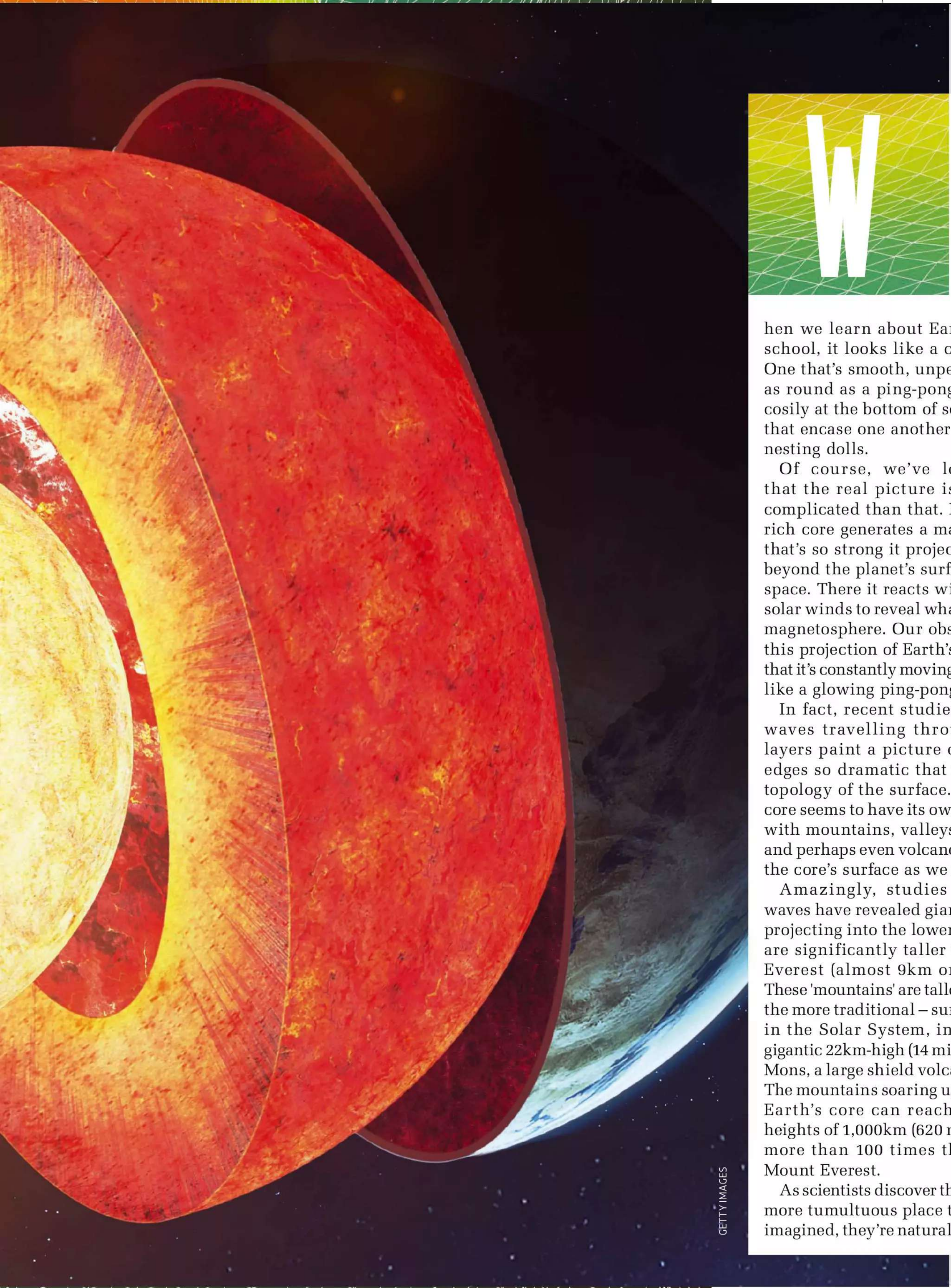
THE SECRETS OF THE INNER EARTH

Deep beneath our feet, at the border between Earth's core and the mantle above, scientists are discovering a hidden world – another landscape with a surface almost as dynamic, dramatic and diverse as the one we live on

by **COLIN STUART**



GETTY IMAGES

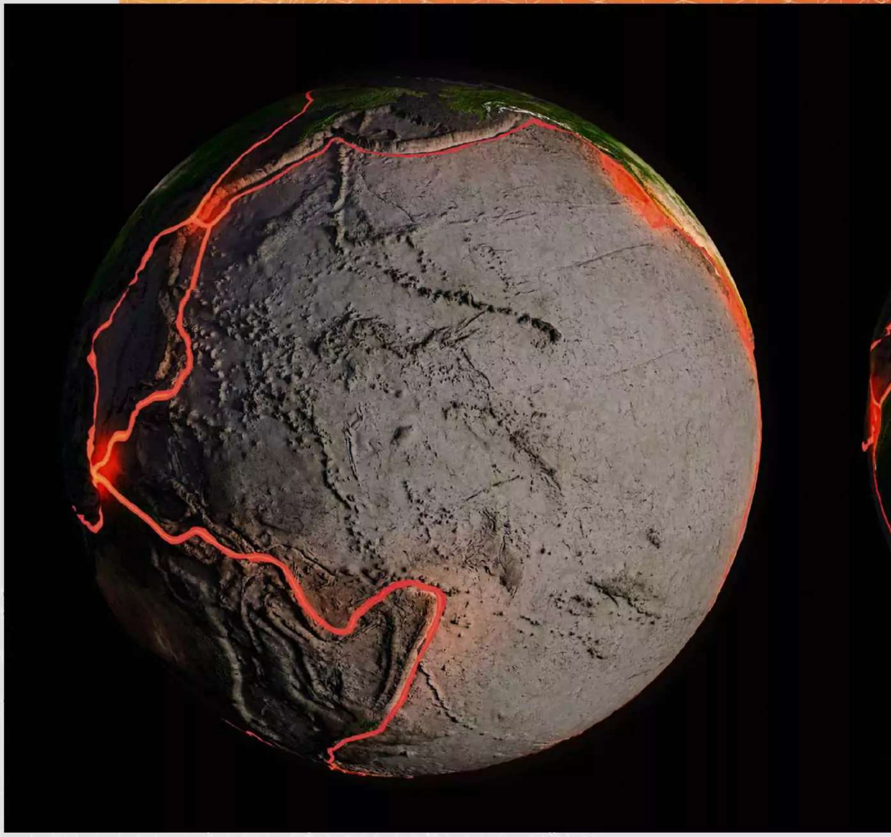
When we learn about Earth's core at school, it looks like a calm sphere. One that's smooth, unperturbed and as round as a ping-pong ball. It sits cosily at the bottom of several layers that encase one another like a set of nesting dolls.

Of course, we've long known that the real picture is a lot more complicated than that. Earth's iron-rich core generates a magnetic field that's so strong it projects outwards beyond the planet's surface and into space. There it reacts with the Sun's solar winds to reveal what we call the magnetosphere. Our observations of this projection of Earth's core tell us that it's constantly moving and nothing like a glowing ping-pong ball.

In fact, recent studies of seismic waves travelling through Earth's layers paint a picture of the core's edges so dramatic that it rivals the topology of the surface. Indeed, the core seems to have its own landscape, with mountains, valleys, landslides and perhaps even volcanoes changing the core's surface as we map it.

Amazingly, studies of seismic waves have revealed giant structures projecting into the lower mantle that are significantly taller than Mount Everest (almost 9km or 5.5 miles). These 'mountains' are taller than any of the more traditional – surface – peaks in the Solar System, including the gigantic 22km-high (14 miles) Olympus Mons, a large shield volcano on Mars. The mountains soaring upwards from Earth's core can reach staggering heights of 1,000km (620 miles). That's more than 100 times the height of Mount Everest.

As scientists discover the core is a far more tumultuous place than we ever imagined, they're naturally starting →



→ to ask if it has always been like this. That's the key question at the heart of a handful of projects using seismic waves to chart the core's changing surface. But what's more exciting is that for every mystery they appear to solve, another anomaly seems to surface in their findings.

AN ORIGIN STORY

Earth has two particularly large subsurface mountains, one hidden under Africa and another nestled deep below the Pacific. Both are about 2,000km (1,250 miles) beneath the surface, making them five times further away from us than the astronauts aboard the International Space Station.

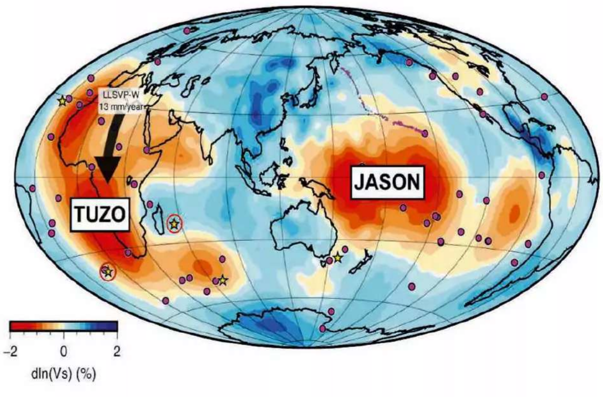
The mountain under the Pacific is colossal, spanning about 3,000km (1,800 miles) – almost as wide as the Moon. Together, these mountains are big enough to account for six per cent of Earth's entire volume. It's an unfathomable amount, but to put it in some sort of perspective, consider Earth's vast oceans: they cover enough of the surface for us to refer to it as the Blue Planet, and yet all of the Earth's vast oceans constitute just 0.12 per cent of the planet.

The subsurface behemoths have been named Tuzo and Jason, after the geologists Tuzo Wilson and W Jason Morgan. And while they're often referred to as mountains, technically they're large low-velocity provinces (LLVPs). In other words, they're areas that slow seismic waves down.

The effect they have on seismic waves was how they were discovered – initially in the 1980s, with further insights after a 1994 earthquake in Bolivia. "Nobody knew if [LLVPs] were only a temporary phenomenon, or if they've been sitting there for millions, perhaps even billions, of years," says Prof Arwen Deuss, a seismologist at Utrecht University in the Netherlands.

The LLVPs are surrounded by regions known as 'slab graveyards'. They're the final resting places of ill-fated tectonic plates. Tectonic plates are the interlocking puzzle pieces that comprise Earth's surface. When two plates rub up against one another, it can trigger an earthquake. But one plate can also slide beneath the other – a process known as subduction. A subducting plate can sink all the way down through the mantle, becoming the geological equivalent of a shipwreck on the mantle floor – close to where it meets Earth's core.

> "THIS SLAB OF CRUSTAL MATERIAL BEGAN SINKING 250 MILLION YEARS AGO"



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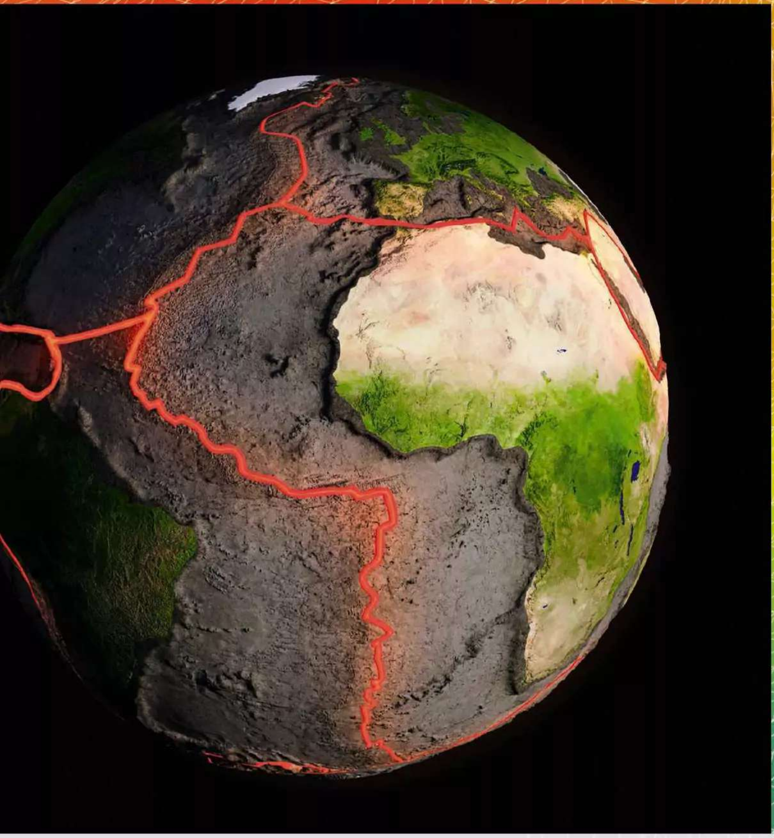


Recent research into LLVPs is calling into question what we thought we knew about these regions, however. Deuss led a team looking at how seismic waves lose energy – or are 'damped' – as they pass through LLVPs. Contrary to what they expected, Deuss's team found that the waves lost very little energy. Much more energy was lost when the waves passed through the neighbouring slab graveyards.

After careful analysis, Deuss's team concluded that the difference was down to the size of mineral grains that form the plates and mountains. The grains in the graveyard plates are small and tightly packed, meaning it's harder for seismic waves to pass through. "The fact that the LLVPs show very little damping, means that they must consist of much larger grains," Deuss says.

This discovery has important consequences for our understanding of Earth's mantle as a whole. Big grains take far longer to assemble than smaller ones, meaning the LLVPs must be old – perhaps half a billion years old. The mantle is usually considered to be a region of 'fast-flowing' material that's well-mixed and constantly churning with eddies and currents, like the oceans above. And yet these new results are hinting that massive structures, such as Tuzo and Jason, can persist for hundreds of millions of years.

ABOVE Subduction zones, where one plate is pushed below another before sinking into the mantle, form at the boundaries between Earth's tectonic plates

ABOVE RIGHT Seismologist, Prof Arwen Deuss

FAR LEFT A map showing the approximate positions of the two large low-velocity provinces known as Tuzo and Jason

SINKING PLATES, RISING MOUNTAINS

They could even be far older. There's a persistent and entrancing idea that these continent-sized structures in Earth's mantle are giant fragments of a planet that hit Earth in its earliest days. Astronomers think that the debris from this collision snowballed into the Moon. The fact that the grain sizes in the LLVPs are different to those in the surrounding tectonic plate graveyard, only adds to the intrigue.

A new study from March 2025 seems to pour cold water on the Moon link, however. A team led by Dr James Panton at Cardiff University found that Tuzo and Jason have different compositions. "We find the Pacific LLVP to be enriched in subducted oceanic crust, implying that Earth's recent subduction history is driving this difference," he says.

This is just one way in which scientists are starting to learn more about the way material from Earth's surface sinks into the mantle. In October 2024, seismologists announced that they'd discovered a chunk of what was once the sea floor hiding in the mantle under the Pacific close to Easter Island. This slab of crustal material began sinking 250 million years ago, at a time when the first dinosaurs appeared and all our modern continents were joined together. →

ABOVE Geophysicist Prof Hrvoje Tkalčić

LEFT Ultra-low velocity zones have been spotted under the volcanic islands of Hawaii

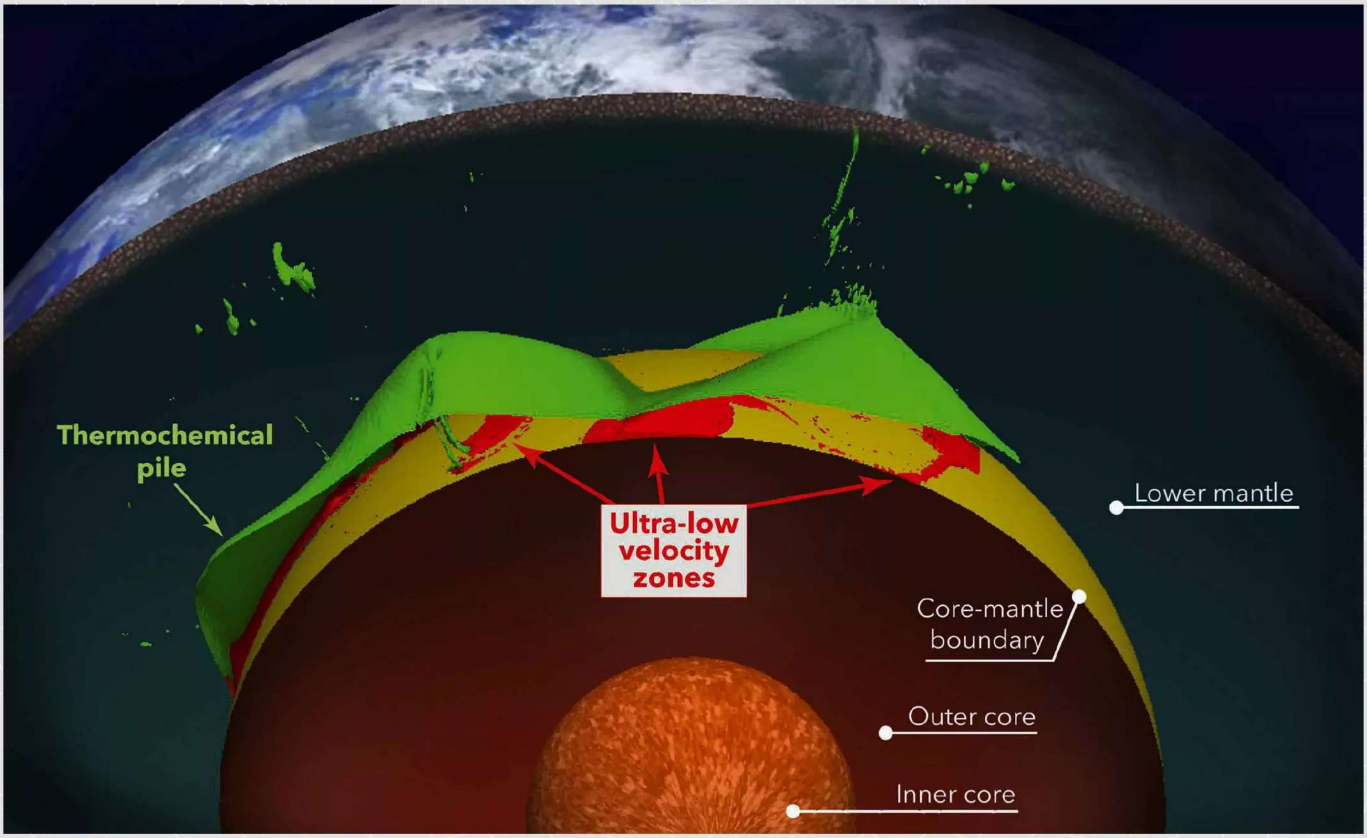
BELOW Ultra-low velocity zones sit near the mantle floor

→ That discovery was quickly followed by another in November 2024. A team led by Thomas Schouten, from ETH Zurich Geological Institute in Switzerland, used a new type of seismographic imaging to spot numerous patches in the mantle that appear, at first glance, to be subducted tectonic slabs. Except they're all in the wrong places. You'd expect them to be beneath joins in tectonic plates, but some of them are found in places that, as far as we know, have never experienced tectonic activity, such as below the western Pacific Ocean.

"With the new high-resolution model, we can see such anomalies everywhere in Earth's mantle. But we don't know exactly what they are," Schouten says. Seismic waves move through these regions at the same speed as they move through subducted slabs, but that doesn't necessarily mean that's what they are.

Given their sheer abundance, one potential alternative explanation is that they're regions containing ancient, mineral-rich material that's been in the mantle since the start. As such, they could be important 'eyewitnesses' to the birth of this planet. It just goes to show how little we know about the world beneath our feet, its continued ability to surprise us and its importance in understanding how we came to be here.

There may be other records of Earth's past lurking in the lower mantle, close to the boundary with the planet's core. Last August, a team led by geologist Dr Michael Thorne at



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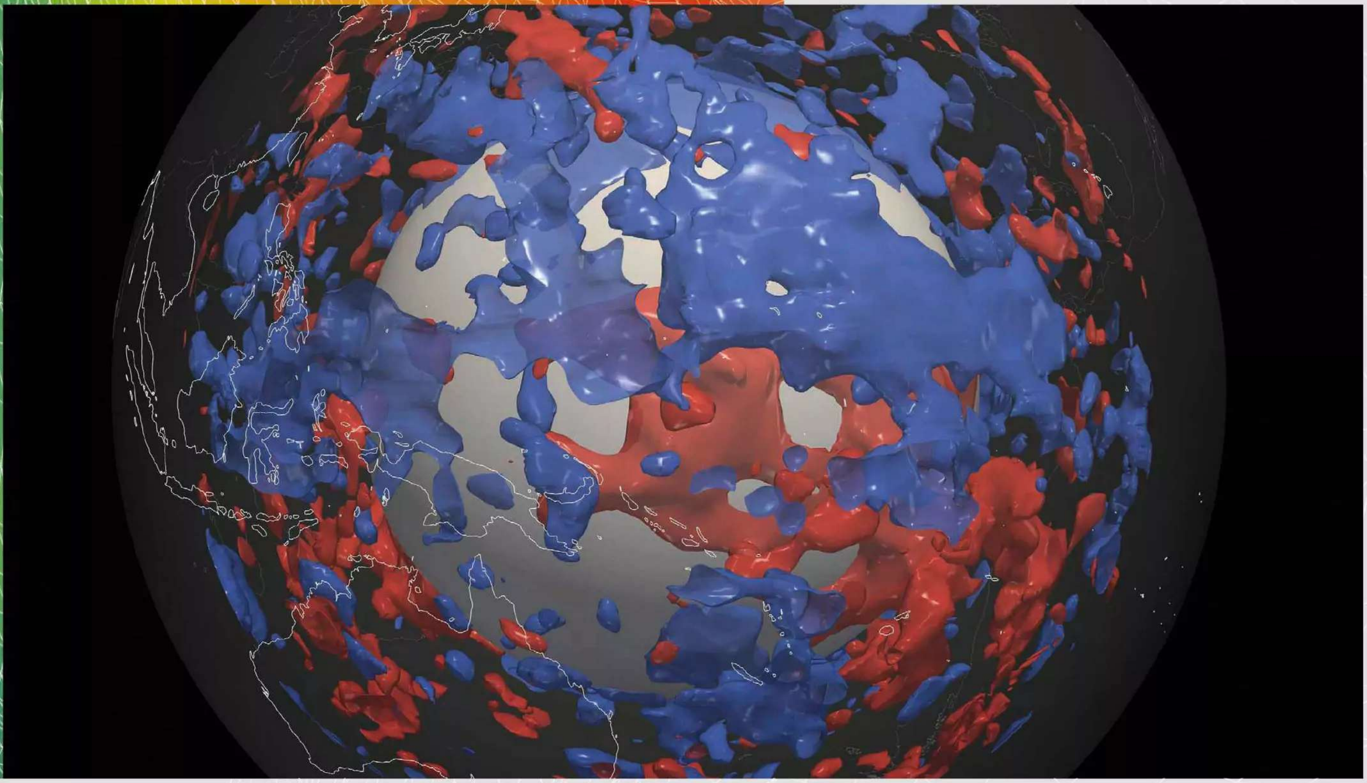


"WITH THE NEW HIGH-RESOLUTION MODEL, WE CAN SEE ANOMALIES EVERYWHERE IN EARTH'S MANTLE"

the University of Utah found evidence for an extensive network of so-called Ultra-Low Velocity Zones (ULVZs). Seismic waves rippling through these regions can slow down by up to 50 per cent.

We knew about these zones before, finding them near hotspots like the volcanic islands of Hawaii. Yet Thorne's research shows that they're everywhere, including under North Africa, East Asia and the Pacific Northwest. "These are some of the most extreme features discovered on the planet," Thorne says.

Previously, scientists had suspected that ULVZs could be fragments of the space rocks that regularly rained down on Earth in its youth. But the fact that they appear to be so widespread suggests that they're more modern and are perhaps being actively generated today. The exact mechanism remains unclear, but one idea put forward by Thorne is that material around tectonic mountain ranges on the sea floor – known as mid-ocean ridges – is melting. This material is then scattered through the mantle where it accumulates at the boundaries of the LLVPs.

ABOVE A recent study has shown how different densities of material in Earth's lower mantle affect the speed at which seismic waves pass through it – slower through the red areas, but faster through the blue ones

MORE DISRUPTIVE DISCOVERIES

Drop down below the mantle and you reach Earth's core. Split into the inner and outer core, the whole thing has a diameter just shy of 7,000km (approx 4,300 miles). That makes Earth's core marginally bigger than the planet Mars. It's like having a planet within a planet and, indeed, the core has many otherworldly properties. For one thing, the inner core is almost as hot as the surface of the Sun.

In August 2024, Dr Xiaolong Ma and Prof Hrvoje Tkalčić, a seismologist and geophysicist, respectively, both at the Australian National University, discovered a large, doughnut-shaped region of the core parallel to Earth's equator. Seismic waves travel through the region approximately two per cent slower than in the rest of the core. The pair estimates →

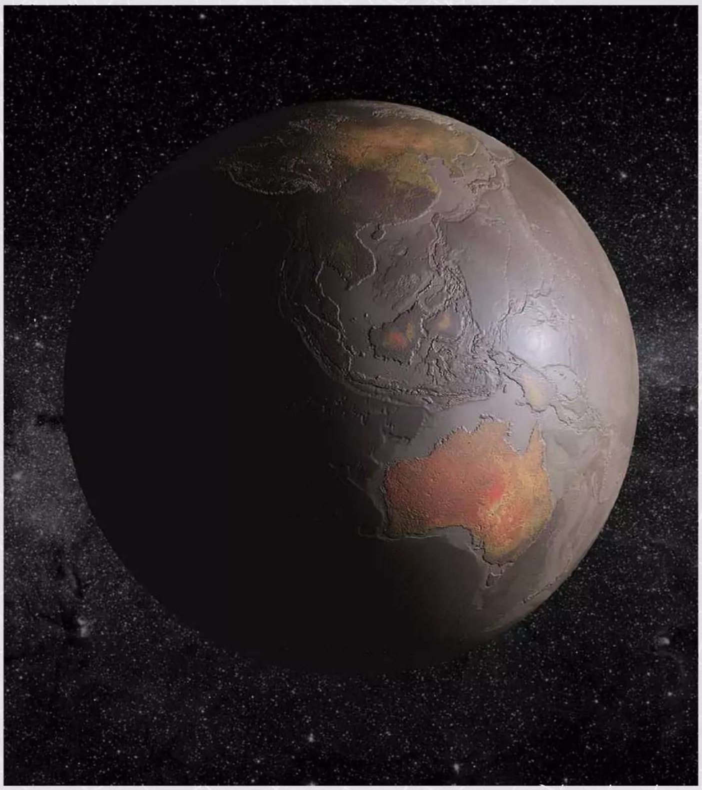
> “THE CORE HAS ALWAYS BEEN A BELLWETHER FOR THE CURRENT STATE OF EARTH”

→ that this area is just a few hundred kilometres thick. “We think this region contains more lighter elements, such as silicon and oxygen, and may play a crucial role in the vast currents of liquid metal running through the core that generate Earth’s magnetic field,” says Tkalčić.

Earth’s inner core may even have changed shape within the last 20 years, according to a separate study led by Prof John Vidale, a seismologist at the University of Southern California. The inner core of Earth is solid and rotates independently from the molten outer core. Vidale thinks he’s spotted small, 100m-long (almost 330ft) deformations where the top of the inner core meets the outer core.

“The molten outer core is widely known to be turbulent, but its turbulence had not been observed to disrupt its neighbour, the inner core, on a human timescale,” Vidale says. “What we’re observing – for the first time – in this study, is likely to be the outer core disturbing the inner core.” According to Vidale, such disturbances could even lead to volcanoes bubbling up along this boundary, alongside giant landslides. Although the sheer distances involved make these tricky things to prove conclusively.

BELOW Without the magnetosphere generated by the core, Earth would have no protection from solar wind and eventually become a barren, lifeless rock



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EARTH’S END

These changes are, perhaps, the beginning of the end for Earth and its habitability. Inch by inch, the molten outer core is freezing onto the solid inner core. When it solidifies completely in a few billion years’ time, Earth’s magnetic field will switch off leaving us unprotected from the ravages of the Sun and its solar wind. This stream of charged particles will gradually peck away at the planet’s atmosphere as it once did to Mars, turning Earth into a barren, lifeless wasteland.

The core has always been a bellwether for the current state of Earth. The modern core could even still hold clues as to how quickly the planet formed in the first place. It all comes down to a rare form of helium known as helium-3.

Helium is so light that it easily escapes from Earth’s gravitational clutches and leaks into space. However, the core could have imprisoned a supply of helium-3 when it formed from the giant cloud of gas and dust that was the early Solar System. The trouble is that the core is largely made of iron and scientists have traditionally thought that iron and helium don’t mix. Now a new study by researchers at the University of Tokyo in Japan has called that idea into question.

If helium-3 and iron do indeed mix, working out how much helium-3 there is in Earth’s core could help settle a longstanding debate about how quickly the planet formed. If, as is most widely believed, Earth took about 100 million years to form, then the core won’t contain much helium-3, as it had ample time to leak out. A much higher level of helium-3 would suggest that Earth formed considerably faster.

Slowly but surely, geologists and seismologists are piecing together the clues that will allow them to pull back the proverbial curtain and learn the hidden secrets of Earth’s inner layers. To date, they’ve revealed a region more mysterious and confounding than they had imagined. So, for now, we have more questions than answers. But the more we discover, the more we’ll understand about the history of Earth and how it is that we came to call it home. **SF**

by **COLIN STUART**

Colin is an astronomy author and speaker.

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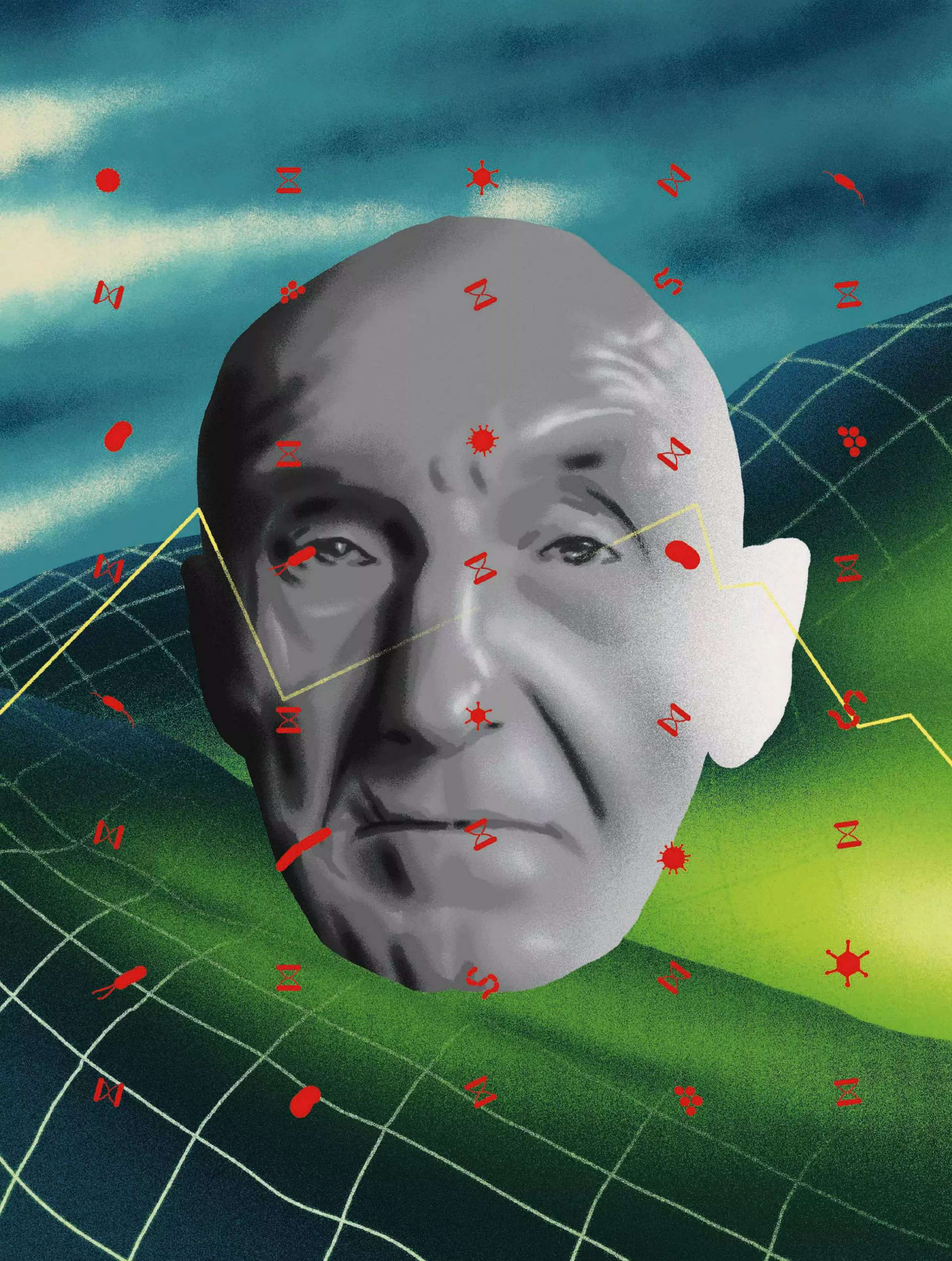


GUT REACTION

Scientists have been telling us for years that if we love our gut bacteria, they'll love us back and help us with everything from easing digestion to fighting disease. Now, new research suggests that our microbiomes can even help us resist the effects of ageing… if we treat them right

by DR HELEN PILCHER

ILLUSTRATION: BERNARD LEONARDO

Take a stroll through the supermarket and you'll find plenty of products stuffed with 'friendly bacteria.' Bacteria – the good guys! Chug them down and they'll help to look after you. We're used to the idea that our guts are teeming with microbes and that they can be topped up with fancy yoghurts. We give the bacteria somewhere to live and, in return, they help us to digest our food. It's a mutually beneficial, two-way street.

Only this cosy relationship isn't quite what it seems.

Hidden among their ranks is a dark cabal of interlopers. To call them 'unfriendly bacteria' would be an understatement. These are microbial hell-raisers and as we get older, they slowly start to wreak havoc.

> "OUR GUT BACTERIA PLAY A KEY ROLE IN MANY NEGATIVE ASPECTS OF AGEING"

It turns out that our gut microbes aren't always the good guys we think they are. A growing body of evidence suggests that our gut bacteria play a key role in many of the negative aspects of ageing, such as disease, frailty and the faltering of the immune system. But all isn't lost. We may not be able to stop getting older, but as we learn to harness the power of the microbiome, we can use it to help us age better and avoid ill health.

GOOD BIOME, BAD BIOME

The gut microbiome is made up of over 100 trillion microorganisms, including various bacteria, viruses and fungi. Round them up and they would weigh about as much as a hamster. If you leave them be, though, they can be found throughout the entire length of the human gut, all the way from the mouth to the anus. →

→ Established at birth, the gut microbiome develops through early childhood. Its makeup is a reflection of what we eat, where we live and what we do. Colonies of bacteria are laid down – some good, some bad, others somewhere in between – that then remain broadly stable for decades.

During this time, the good guys predominate. They assist us by breaking down dietary fibre, which releases energy that we can use, and by making nutrients, such as vitamin K and folate. In addition, they help to keep the bad guys in check and prevent them from making us sick.

So far, so good. But then, from age 50 or so onwards, the composition of our gut microbes starts to change.

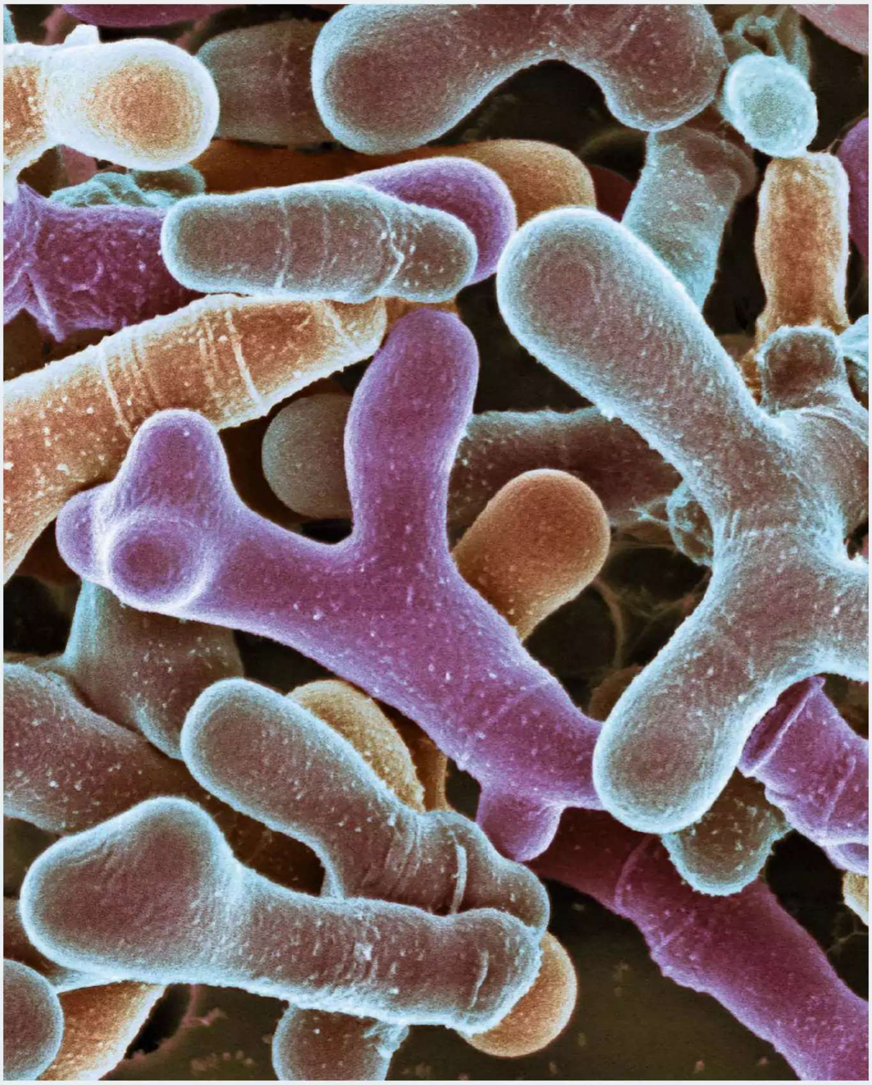
The good guys, such as *Roseburia* and *Bifidobacterium*, start to decline, while the bad guys, such as *Escherichia* and *Streptococcus*, start to increase. Overall, there's a loss of diversity. "The composition and the function of the microbiota start to change," says Dr Aimée Parker from the Quadram Institute in Norwich.

Compare the gut microbiome of a group of 80-year-olds with a group of 18-year-olds and they look very different. There are also differences between the gut microbiomes of healthy older adults and older adults who suffer from frailty, thinning bones, Alzheimer's disease and Parkinson's disease.

Studies have highlighted distinct microbial signatures associated with type 2 diabetes, cardiovascular disease and colorectal cancer – all diseases that become more common from mid-life onwards – but, for a while, no one knew whether these features were a cause or an effect. Does the microbiome drive ageing and age-related disease, or does ageing and ill health lead to changes in the microbiome?

THE EFFECTS OF AGEING

The answer, we now realise, is both. Age-related changes to the gut have an effect on bacterial composition, as do illness, poor diet, physical inactivity and the use of certain medicines, which all become more common as we get older.



"COMPARE THE GUT MICROBIOME OF A GROUP OF 80-YEAR-OLDS WITH A GROUP OF 18-YEAR-OLDS AND THEY LOOK VERY DIFFERENT"

ABOVE A coloured electron micrograph of *Bifidobacterium animalis*, a probiotic bacteria found in the large intestine

TOP RIGHT Mucin is produced by the colon

RIGHT The abundance of certain strains of *Escherichia coli* (*E. coli*) bacteria found in our guts increases with age

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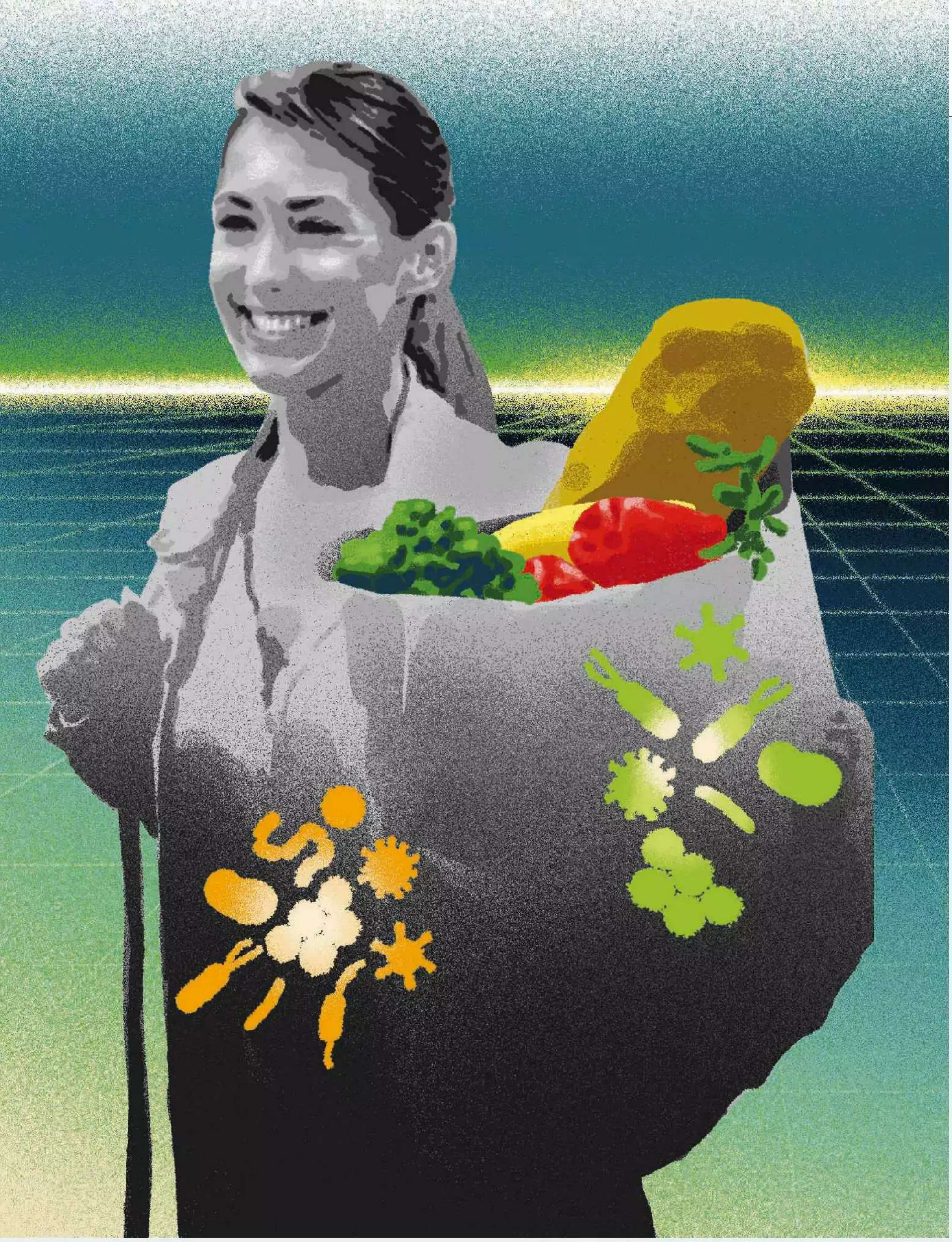

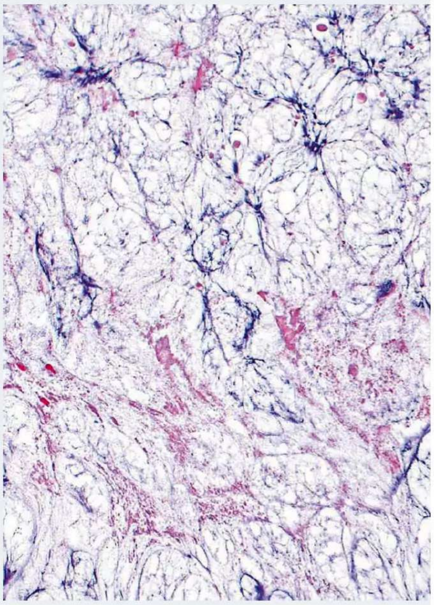

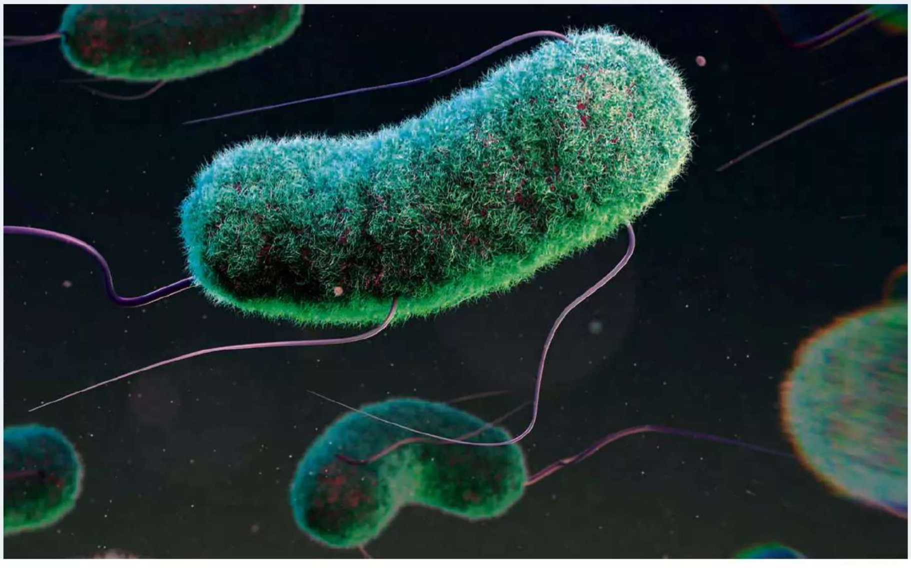

The relationship goes in the other direction too, though. Alongside the various factors that we already know more about, such as genetics and lifestyle choices, the gut microbiome is one of the things that actually drives ageing.

We've arrived at this knowledge mainly thanks to information gathered through experiments known as 'Faecal Microbial Transplants' (FMT) or, more colloquially, 'poo transplants.' They do exactly what the name suggests. Faeces are teeming with gut microbes. In carefully monitored studies, faeces from old animals can be transferred to the guts of young animals, which are then monitored over time.

When the experiment is performed on flies, it shortens their lives. When it's performed on mice, the animals show signs of memory impairment.

Effects can be seen throughout the body, at the level of molecules, cells and even whole organs. Parker has shown that young mice who receive 'old' microbes, develop age-related changes in the gut, eyes and brain. A key protein required for vision becomes depleted, while levels of inflammatory markers in the brain increase. →

→ "What happens in the gut, doesn't stay in the gut," says Parker. "It affects the rest of our bodies."

The picture that now emerges is that as the 'bad guys' start to take over, the gut wall starts to deteriorate. 'Friendly bacteria' stimulate the production of a slimy protein called mucin, which helps to protect the lining of the gut. With less mucin, the lining becomes damaged. The gut becomes inflamed and leaky. Microbes and the products that they make, leach into the body and are carried to distant places in the bloodstream.

This doesn't go unnoticed by the immune system, which springs into action, triggering a chronic, low-level inflammation known as 'inflammageing.' This isn't good. Inflammageing is widely recognised as a sign, or 'hallmark', of ageing, which plays a role in the development of many age-related diseases, including cancer and cardiovascular disease.

In addition, the immune system itself becomes aged. Microbial products reach the thymus, a plum-sized gland that sits above the heart and is part of the immune system. It makes specialised immune cells, called T cells, which help the body fight infection. The thymus is known to

TOP LEFT Research into faecal microbial transplants has produced vital information on how the microbiome can affect the ageing process

ABOVE LEFT A petri dish containing cultures of donor stool samples being tested ahead of a faecal microbial transplant

LEFT Syringes containing a stool solution are prepared for a faecal microbial transplant to treat patients with colon infections

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“EVEN IF THE SLIDE TOWARDS MICROBIAL DISORDER CAN’T BE ENTIRELY PREVENTED, IT CAN CERTAINLY BE SLOWED”

shrivel with age, but Dr Niharika Duggal from the University of Birmingham has shown that this shrinking may be driven by the ageing and increasingly disordered microbiome.

“We think this could be contributing to the senescence we see in your thymus as you get older,” she says. Indeed, Duggal has shown that adults who have leakier guts also have older and more exhausted T cells.

SLOWING THE DECLINE

So, how do we protect ourselves from this microbial mayhem? “The good news is that the microbiome is very malleable,” says Duggal. Even if the slide towards microbial disorder can’t be entirely prevented, it can certainly be slowed, which is almost as beneficial.

To see the effects of this, researchers have performed ‘reverse’ faecal transplants, where the microbes of young mice are manoeuvred into the guts of old mice. The gut becomes less leaky, inflammation is reduced and the immune system shows signs of becoming healthier. Hallmarks of ageing in important organs, such as the eyes and brain, also decrease. The older mice even show improvements in cognitive function and their memories start to improve.

Buoyed by these findings, researchers at the Quadram Institute in Norwich are setting up an FMT facility to trial faecal transfers for people. Presently, the technique is used in the clinic, but only for the treatment of hard-to-shift *C. difficile* infections. Patients receive transplants from healthy, screened donors, which are given either by colonoscopy, endoscopy or a tube that goes up the nose and down into the stomach. The procedure is highly effective, with a success rate of around 85 per cent.

If further pre-clinical studies go well, Parker hopes to test the effects of FMT on ageing in humans. “We’d like to see if there are differences in measures such as frailty, visual ability and cognitive performance,” she says.

For many people, however, even the thought of a faecal transplant can be butt-clenching. So, researchers are developing alternate methods, including freeze-dried faecal transplant capsules, which, they hope, will be easier to swallow.

Another potential approach to combat the worst effects of ageing, is to boost levels of the ‘good guys’ by taking prebiotic and probiotic supplements. Prebiotics are fibre-based products that promote the growth of healthy gut bacteria, while probiotics contain the ‘good guys’.

Lots of people buy the supplements off-the-shelf and swear that they feel better for taking them, but their ability to influence ageing in the long term is only just starting to be explored.

Early studies are cautiously optimistic. In one, where older people took a prebiotic supplement for three months, measures of frailty decreased. In others, where older people received probiotic supplements, markers of inflammation were reduced. →

→ Research is hotting up, with animal studies hinting at further benefits. One study, from this year, found that a combined pre- and postbiotic (postbiotics are the chemicals produced by healthy gut bacteria that are thought to cause their positive effects – butyrate is one example) treatment reduced cardiac muscle damage in an animal model of heart disease.

Another study, also from this year, found that a unique cocktail of 10 probiotics eased signs and symptoms of Alzheimer's disease in a mouse model of the condition. Cognitive decline was slowed, and brain markers of the neurodegenerative condition were reduced. The study's authors called the results "remarkable."

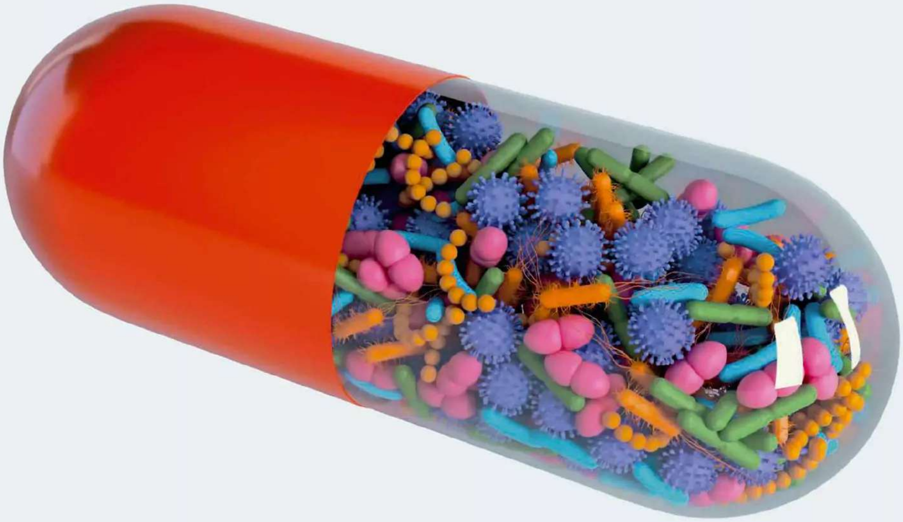
Another possible approach involves taking postbiotics. Studies suggest that Butyrate, a short-chain fatty acid, may be able to help reduce inflammation, keep the gut wall healthy and help to protect against colon cancer.

Butyrate can be bought online (it tastes awful), but researchers caution against rushing to buy it, or any of the pre- and probiotic supplements that are available. This is because, although the microbiome is highly malleable, it's almost impossible to know what blend of supplements your unique gut needs.

Microbiome tests are available, but by the time you get the results, they'll already be out of date because the microbiome is constantly changing in response to diet, activity and other factors. So, you can take a probiotic anyway, but there's no way to know if the bacteria will bed down in your gut and do something useful or pass straight through and come out the other end.

Even if your test highlights something noteworthy, such as a missing strain of 'good bacteria', it's entirely possible that you have other 'good bacteria' that already compensate for this imbalance.

"Don't waste your money," says microbiome researcher Prof Fergus Shanahan University College Cork. "One measurement doesn't mean much anyway." Instead, the single best thing that any of



"IF YOU WANT TO PREPARE FOR OLD AGE, IT'S BEST TO START WHEN YOU'RE YOUNG"

us can do to maintain a healthy community of gut bacteria and age well, is to eat a decent diet. "I don't think we should be neurotic, trying to overcomplicate things," says Shanahan. "Just eat more fibre. Fibre is microbe food."

Study after study shows the benefits of adhering to a 'Mediterranean diet,' rich in vegetables, fruits, fish, olive oil and nuts, and low in red meat, dairy and saturated fats. Sticking to the plan is already known to improve longevity and reduce the risk of chronic diseases, such as heart disease, cancer and diabetes, but the colourful diet can help beyond this.

In the biggest study of its kind, researchers investigated what happened to the gut microbiomes of 612 healthy adults – all aged over 65 – who ate either a Mediterranean diet or their normal diet. One year on, those who had been eating Mediterranean-style had more of the gut bacteria that are linked to healthy ageing. This included more of the 'good guys' that are associated with lower frailty and better brain function, and less of the 'bad guys' that are associated with inflammation.

ABOVE Fruits, vegetables, healthy oils and fish make up a significant proportion of the Mediterranean diet

LEFT Scientists are already working to make microbial transplants via capsule a reality

GETTY IMAGES X2

The study provides the first clear evidence that eating a healthy, fibre-rich diet can help to rein in the gut bacteria known to drive unhealthy ageing and disease, but we don't need to wait until we're in our sixties to reap its benefits.

"If you want to prepare for old age, it's best to prepare when you're young," says Shanahan. "The one thing we can all do to help deterioration in old age, is to add diversity to our diet now." **SF**

by **DR HELEN PILCHER**
Helen is a science writer with a PhD in cell biology.

THE BIG QUESTION

Are statins the best way to lower my cholesterol?

Statin use is already widespread and is increasing every year. But are the drugs right for everyone?

by **HAYLEY BENNETT**

More of us than ever are taking statins. The National Institute for Health and Care Excellence (NICE) reported in October 2024 that around 5.3 million people in England had taken statins or the cholesterol-lowering medication ezetimibe in the previous year. That's almost triple the figure for 2015/2016 and approaching 10 per cent of the country's population. Meanwhile, statin use is also increasing globally.

Doctors prescribe statins to help prevent heart disease – currently the leading cause of death worldwide. They reduce low-density lipoprotein (LDL) cholesterol – the 'bad' type that clogs up arteries – by interfering with enzymes that our livers use to make cholesterol and helping draw it out of the blood. This makes statins effective at preventing heart attacks and strokes, but that alone doesn't answer all the questions people have before they decide to start taking drugs like these. Questions like: if I have high cholesterol, do I have to take statins? Can I try changing my diet and doing more exercise first? And what kinds of side effects can I expect if I do start taking statins?

> **"Statins are probably the most widely studied drugs in medical history"**

The answer to the first two questions is the same: it's up to you. The decision to start taking statins is one you should arrive at with the help of your doctor, and it should be based on your overall risk of heart disease – not just your cholesterol level. That means considering other risk factors such as your blood pressure, family history and even your postcode.

As Julie Ward, a senior cardiac nurse at the British Heart Foundation, explains, doctors use all this information to calculate your personal cardiovascular risk score, which tells you how likely you are to have a heart attack or stroke in the next ten years.

"Once that cardiovascular risk score comes back, conversations can start about what we can do to reduce that risk," says Ward. "So, it really is a conversation between the person and the [doctor] or pharmacist. It's not just, 'This is your cardiovascular risk. We're going to start you on a statin.'"

SCIENCE PHOTO LIBRARY

In England, prescriptions for NICE-recommended statins or the medication ezetimibe rose by 19 per cent from 2022 to 2024

That conversation might start with lifestyle changes, such as eating more healthily or stopping smoking.

You can calculate your risk score using an online calculator, such as the one at bit.ly/CVriskcalc. The higher your ten-year risk, the more likely that statins will be up for discussion. You might decide your risk is low enough to warrant a diet and exercise plan instead, before revisiting the calculator a few months later to see if it's changed. But what if statins are strongly recommended?

ABSOLUTE RISK

It's understandable to feel apprehensive about starting a drug you might have to take for the rest of your life. But here the science may provide some reassurance, because there's a wealth of evidence showing statins are effective for preventing heart disease – and with only mild side effects, according to Prof James Sheppard, a health data scientist at the University of Oxford.

"Statins are probably the most widely studied drugs in medical history," he says. "There are hundreds and hundreds of clinical trials looking at statins."

Researchers have also pulled together the results of large collections of these trials to help strengthen the evidence. In 2015, for example, researchers working for Cochrane, a world-renowned publisher of medical reviews, pooled data from nearly 39,000 people who took part in 296 trials on atorvastatin, the most widely prescribed statin. Overall, their review showed that taking atorvastatin for up to 12 weeks decreased LDL cholesterol by 37–52 per cent, depending on the dosage.

But how much does taking a statin reduce your risk of dying from a heart attack or other cardiovascular cause? Well, that depends on who you are. A review of clinical trials published in early 2025 puts the figure at anywhere between 20 and 62 per cent, with the higher figure being for higher-risk groups.

These are good reductions from drugs that cost less than £2 (approx $2.50) per 28 tablets. We still need to be careful about how we interpret the figures for our own decision-making, however. In large trials, the effects are often reported in relative terms, meaning they reflect the difference compared to not taking a statin. But, as Sheppard points out, "What's important when you're thinking about who you should treat in the real world is the absolute risk."

So, for example, if taking a statin reduces the risk of having a heart attack by 20 per cent, for someone whose absolute risk (or cardiovascular risk →

→ score) is only 1 per cent, taking a statin would only reduce their risk from 1 to 0.8 per cent. Someone with a risk score over 10 per cent could see much bigger benefits, however.

SIDE EFFECTS MAY VARY

So, we know statins work, but what about the bad press surrounding their side effects? "Press coverage in the past has tainted a lot of people's views," admits Ward. "But through the research, we know that side effects are minimal and statins are extremely well tolerated in the general population."

This is what Sheppard and his team found in a study they published in 2021. They looked at adverse effects from statins across 62 trials, involving more than 120,000 people, and found that only a "tiny number" reported any at all. Around 15 in every 10,000 people experienced pain or other symptoms associated with muscles, while liver, kidney and eye problems were even less common. Yet we know that when people stop taking statins, it's often due to side effects. So, what's going on?

Another 2021 study suggests those side effects may have more to do with our negative associations with taking a pill than with what's actually in it. In the study, 60 people were given 12 one-month supplies of medicine – four bottles with statins, four with dummy pills (placebos) and four with nothing in them. But they didn't know which were statins and which were placebos.

After a year of tracking the participants' symptoms, the researchers found that people did experience more symptoms when they were taking a pill compared to nothing, but that 90 per cent of the symptoms from statins also occurred with placebos.

Of course, that's not to say that if you experience a side effect, you should just grin and bear it. Ward instead suggests you try asking your doctor to adjust the dosage. Atorvastatin, for example, can be given in doses ranging from 10–80mg per day. As side effects tend to be dose-related, 80mg is more likely to cause a problem than 10mg, but wouldn't necessarily be a long-term dosage.

"If somebody has high cholesterol levels, we might start them on 80," says Ward. "Months later, if they're doing great, we can get it down to 40 and then, in a year's time, maybe even 20 or 10, which is called a maintenance dose. And you're very unlikely to have side effects at 10 or 20mg."

Another option is to change pills. Five statins are available on prescription in the UK and although they all work in similar ways, atorvastatin is considered the best. "So, if you were taking a different type of statin at a higher dose, a doctor could prescribe atorvastatin at a lower dose," says Sheppard. "[That] might give you similar cholesterol-lowering effects with fewer side effects."

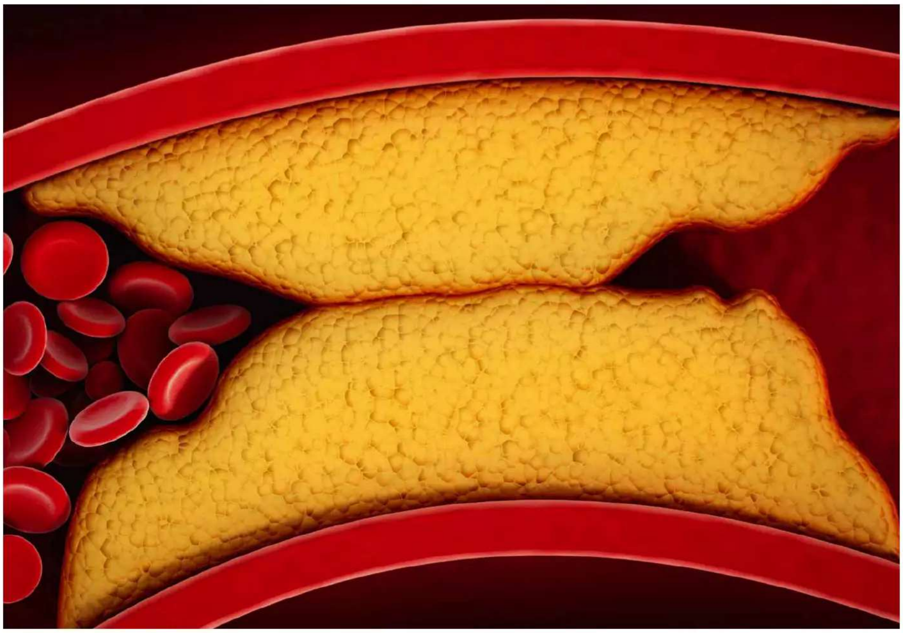
On rare occasions, taking statins can have more serious side effects on the liver and kidneys, but anyone taking statins should have regular blood tests to check for these. People with diabetes may also be concerned about new research showing that statins can raise blood sugar. The beneficial effects of lowering cholesterol are thought to outweigh the harmful effects of slightly increased blood sugar though.

Ultimately, taking statins is a personal decision. If you're worried about it, consider speaking to a cardiac nurse at the British Heart Foundation (bhf.org.uk) or exploring Heart UK's (heartuk.org.uk) resources on cholesterol. **SF**

> **"Press coverage in the past has tainted a lot of people's views. But through the research, we know side effects are minimal"**

by **HAYLEY BENNETT**

Hayley is a science writer based in Bristol, UK.



GETTY IMAGES

Cholesterol can build up in the veins and block them, preventing blood from circulating

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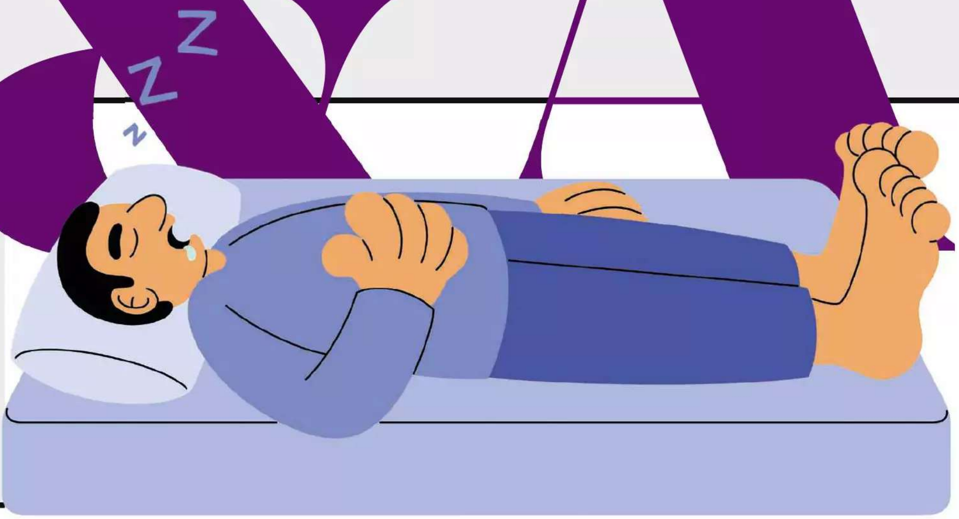


YOUR QUESTIONS ANSWERED

IDRIS WISE, VIA EMAIL

CAN WE COMMUNICATE IN DREAMS?

Today's machine learning methods have been shown to visualise our dreams. But what if we wished to go further and actually share our dreams? At present, while we can interpret brain signals and roughly figure out imagined scenes and high-level thoughts, we have no way to transfer these into another brain. Perhaps that's a good thing: many of us might be a little uneasy at the idea of computers pushing ideas directly into our brains during sleep.

Our only current option is to use our senses. Words spoken into our ears while sleeping might be a way of transferring information from one sleeper to another. But how does a sleeping person talk or listen? It's more difficult than it sounds.

Those who do speak during sleep (called somniloquists) tend to do so because of stress. The strange mumblings and burbles aren't under conscious control. And listening to sounds is also not something we're good at while asleep: noises heard during sleep most commonly result in disturbed sleep and stress for the dreamer.

But there's one kind of dreaming that helps: lucid dreaming. This is a rare kind of dreaming where the dreamer is aware yet still asleep. It can be induced with a bit of practice using various techniques. Perhaps while in this state, two dreamers could actually communicate? A company called REMSpace not only claims that it's possible, but also that they've done it. They used external stimuli to help one sleeper enter a lucid dream state. They then communicated a word to that sleeper via earbuds. The lucid dreamer then repeated the word in their sleep, which was stored on a computer. Eight minutes later, the

DR HELEN SCALES
Marine biology

DR ALASTAIR GUNN
Astrophysics

PETE LAWRENCE
Astronomy

DR HELEN PILCHER
Nature

DR NISH MANEK
The human body

PROF PETER BENTLEY
Artificial intelligence

DR CLAIRE ASHER
Planet Earth

DR EMMA DAVIES
Food & drink

> **"TO INDUCE NEURAL SYNCHRONISATION BETWEEN PEOPLE YOU JUST NEED TO SHARE EXPERIENCES WITH OTHERS"**

message was played to a second lucid dreamer who was able to confirm the word when they woke up. It may be of little use in its current state, but it was communication in dreams.

There's another kind of shared thought that may be a bit more helpful, however. Researchers are now showing that people who work closely together start to synchronise brain waves. It's been likened to the effect when musicians feel perfectly in sync with each other, or when people in a social group feel strongly bonded together.

Inter-brain neural synchronisation, as it's known, has been observed through detailed 'hyperscans' using electroencephalogram (EEG) scanners that measure brainwaves. These might be theta waves (emitted when we're very relaxed), alpha waves (emitted when we're calm) or beta waves (when we're alert and active). When these brainwaves – typically driven by beta waves – synchronise between two or more people, they cooperate better, empathise more and are even less sensitive to pain. Teams that are more in sync at a neural level perform better overall.

The best part is that there's no need for artificial intelligence or brain scanners. To induce neural synchronisation between people you just need to share experiences with others: you could listen to music together, dance or perform together, solve problems together or simply talk to each other. We get this kind of mental sharing for free – and we benefit strongly from it. ***PB***

GETTY IMAGES ILLUSTRATION: JESS LEE

LAYTON HAAS, HAMBURG

HOW IS ANTIMATTER STORED?

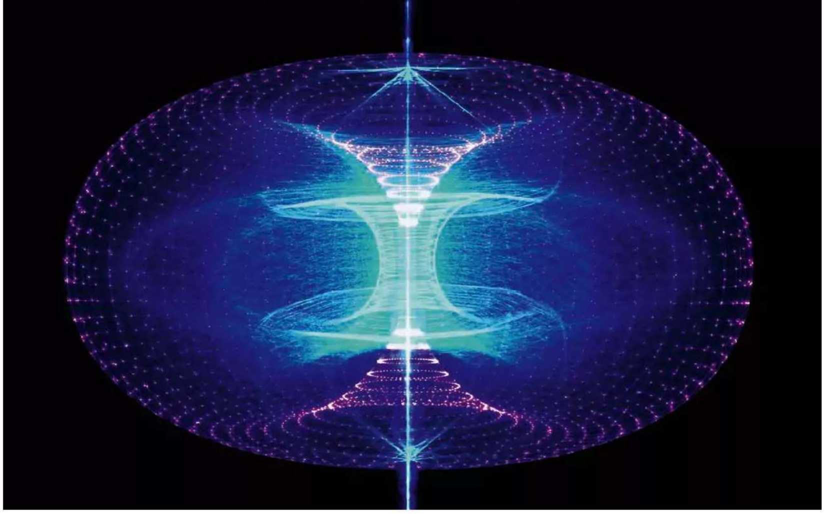
Antimatter particles are almost identical to their normal matter counterparts, except they carry the opposite charge and momentum. Though it's an extremely rare substance, physicists routinely generate antiparticles in particle accelerators. Antimatter is also created naturally in high-energy processes, such as near the event horizons of black holes. How and why the Universe ended up consisting almost entirely of normal matter is an unsolved mystery.

It's extremely difficult and expensive to create antimatter. The European Laboratory for Particle Physics (CERN) produces antimatter in its Antiproton Decelerator instrument, in which a beam of protons slams into a metal target to create antiprotons. But even this produces no more than a few tens of thousands of particles.

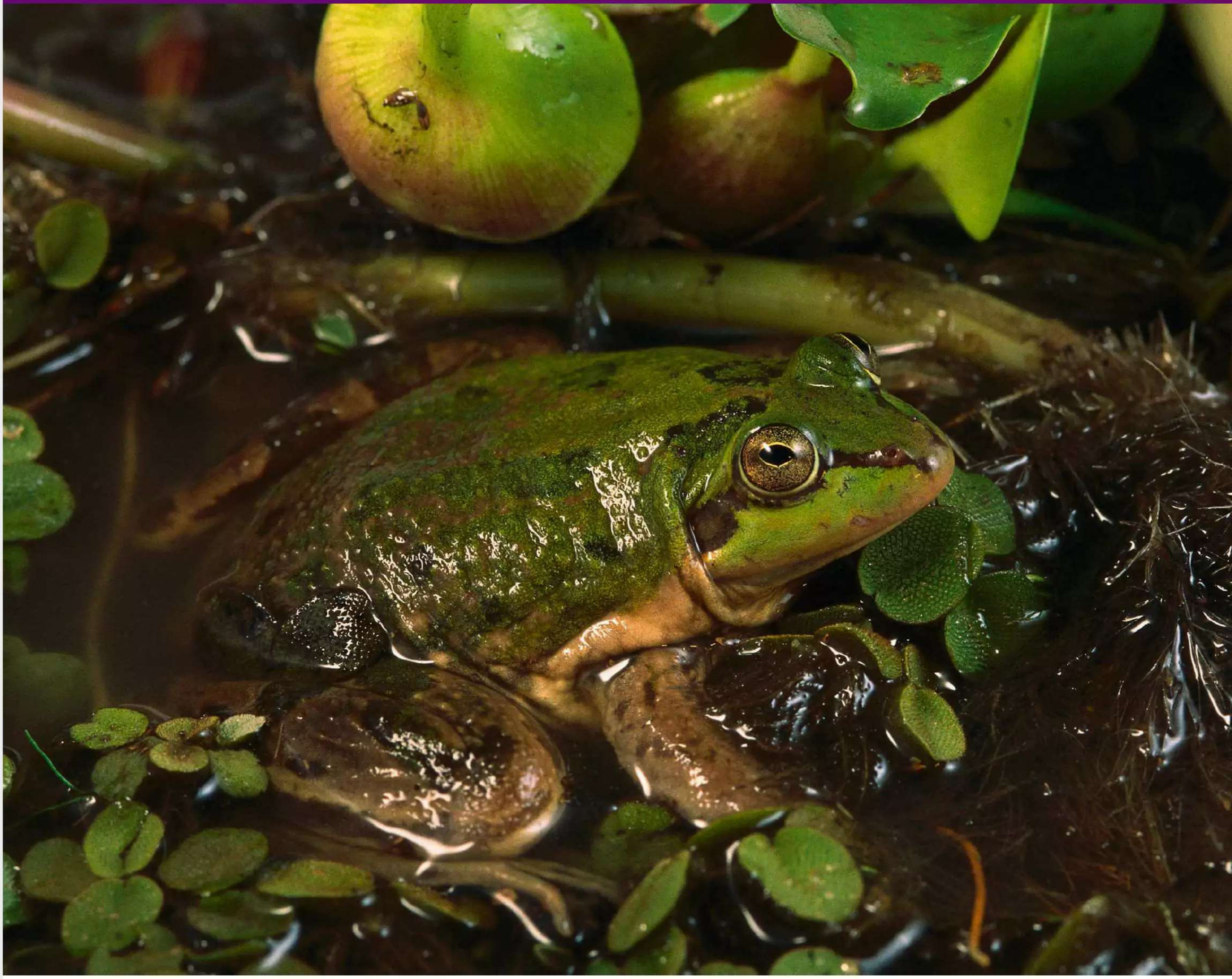
The problem with antimatter is that it completely annihilates itself in a puff of energy when it comes into contact with ordinary matter. So, preventing annihilation and storing it for any length of time is a technical challenge. CERN engineers plan to store (and even transport) small quantities of antiprotons, however.

To do this they'll cool the antiprotons to about -269°C (-452.2°F) to almost stop them moving, then suspend them with superconducting magnets in a very-high vacuum enclosure (to prevent contact with ordinary matter). All this needs to be done while retaining the ability to extract the particles or inject other particles into the enclosure.

Despite the technical challenges, CERN hopes to create a 'trap' that can store up to 1 billion antiprotons for weeks at a time. Recently, the technique was proven by transporting normal matter by truck across the CERN site in Switzerland. With improvements in the vacuum systems, the storage and transport of antimatter should be routine within the next year or so. ***AG***



NATURE'S WEIRDEST CREATURES



THE PARADOXICAL FROG

The world is full of intriguing paradoxes. Does this article still exist when you're not reading it? If I travelled back in time and killed my grandfather, would I still be writing this now? And how can two socks go into the washing machine, but only one sock comes out? Perhaps the biggest paradox, however, is how can a frog get smaller as it grows up?

Life starts, pretty much as expected for the paradoxical frog (*Pseudis paradoxa*). The female lays fertilised eggs in the lakes and lagoons of South America and Trinidad. Eggs hatch, tadpoles emerge and then start to eat. The voracious larvae feed mostly on algae and very soon, start to bulk up. They start small, like other tadpoles, and grow at a similar rate to their non-paradoxical cousins.

If the conditions are right, however, the tadpoles just keep on growing. Bigger than a blueberry. Bigger than a strawberry. Bigger even than a plum. Think 'satsuma stuffed inside an ankle sock,' and you're approaching the right dimensions ... and you've found your missing sock.

With a chunky, rotund body and a long, muscly tail, paradoxical frog tadpoles can reach lengths of up to 22cm (8.6in). To paraphrase the movie *Jaws*, we're going to need a bigger jam jar!

This is around three times bigger than the adult frog the tadpoles will metamorphose into, and most of the development needed to become an adult frog is already complete.

By the time they transition from tadpole to frog, males have well-formed testis and can already produce sperm, while females have the makings of mature eggs. This is different

ALAMY X2 ILLUSTRATION: JESS LEE

“WHY DOES THE TADPOLE PUT SO MUCH ENERGY INTO BECOMING SO BIG IN THE FIRST PLACE?”

to the tadpoles of regular frogs, which take time to become sexually mature after metamorphosis, during the juvenile frog stage of the life cycle.

So, how do the giant tadpoles turn into such little frogs? Easy! At least half of the paradoxical frog’s tadpole is tail. Lose the tail and the paradoxical tadpole turns into a normal, if relatively diminutive adult, with a body length of around 7cm (about 2.5in). This causes the amphibian to ‘shrink’, explaining why it’s also known as the shrinking frog.

Paradox resolved. But just as one conundrum is cracked, another emerges: why does the tadpole put so much energy into becoming so big in the first place?

One possible answer relates to the place and timing of their birth. Paradoxical frogs time mating to coincide with the arrival of the rains.

In Trinidad, this happens around May. Some eggs are laid in permanent pools, while others are laid in more temporary ponds that will later dry up. Those laid in smaller, transient waters, with less food or more aquatic predators, don’t get to grow so big. But those laid in larger, more permanent ponds, with more food and fewer predators, do. In this situation, being big may aid survival, as the fish and other animals that predate smaller tadpoles are less likely to take a bite. ***HP***

SCOTT MILLS, WATFORD

WHAT’S THE WORLD’S OLDEST CHEESE?

The oldest cheese is hard to trace, although we have direct evidence that humans have consumed milk for thousands of years.

Archaeologists have identified milk residues on ancient pots unearthed from many regions of the world. Studying the carbon isotopes of fatty acids in pot residues has revealed that humans consumed milk in Britain from 4000BC and as long ago as 7000BC in Anatolia, a region in Turkey known for its farming during the Neolithic period.

Anatolian farmers migrated far and wide. Milk fat traces don’t often survive millennia underground, but the high number of Anatolian pottery fragments has led scientists to speculate that milk must have been used to create longer-lasting dairy products such as cheese.

Turning the milk into cheese would also have reduced levels of the sugar lactose at a time when lactose intolerance was the norm across Europe. It wasn’t until around 3000 years ago that a genetic mutation became widespread, enabling adults to produce lactase, an enzyme that breaks lactose down to other sugars.

In 2023, a University of York study found protein structures in late Neolithic pots from Poland that were likely to have come from cheese made with milk from cows, goats or sheep.

The oldest cheese samples to survive to this day are around 3,500 years old, found around the necks of Bronze Age mummies in Xiaohe Cemetery in northwest China. A team at the Chinese Academy of Sciences analysed the specimens to identify a kefir (bacteria-fermented milk) cheese. The scientists found DNA from different bacterial and yeast species in the cheese, including *Lactobacillus kefiranofaciens* and *Pichia kudriavzevii*, which are found in kefirs to this day.

They think that the lumps may be kefir starter grains – concentrated bacterial colonies used to kickstart cheese fermentation. At the time, these grains were perhaps considered a precious gift to take into an afterlife. ***ED***

JOSHUA STUCKEY, EXETER

IF AN ADVANCED CIVILISATION LIVED ON EARTH MILLIONS OF YEARS AGO, WOULD WE BE ABLE TO TELL?

Humans have long been fascinated by the possibility of finding technologically advanced beings elsewhere in the Universe, but what if such a civilisation had lived right here on Earth, long before humans evolved?

In 2018, physicist Prof Adam Frank and Dr Gavin Schmidt, a climate modeller, published a paper exploring whether modern scientists would be able to detect evidence of an advanced industrial civilisation that ended millions of years ago. They named this possibility the 'Silurian hypothesis', after an advanced reptilian race from the BBC's long-running sci-fi show *Doctor Who*.

They concluded that while it's extremely unlikely, evidence for such a civilisation might

SARA SOLOMON, VIA EMAIL

SHOULD I GIVE MYSELF A COFFEE ENEMA?

Just when you thought TikTok couldn't come up with anything stranger, here comes the coffee enema. Yes, that's right – people are brewing up a fresh pot, and inserting it into their colon through their rectum to stimulate bowel movements. The trend claims to "detox" your body, boost energy and improve digestion.

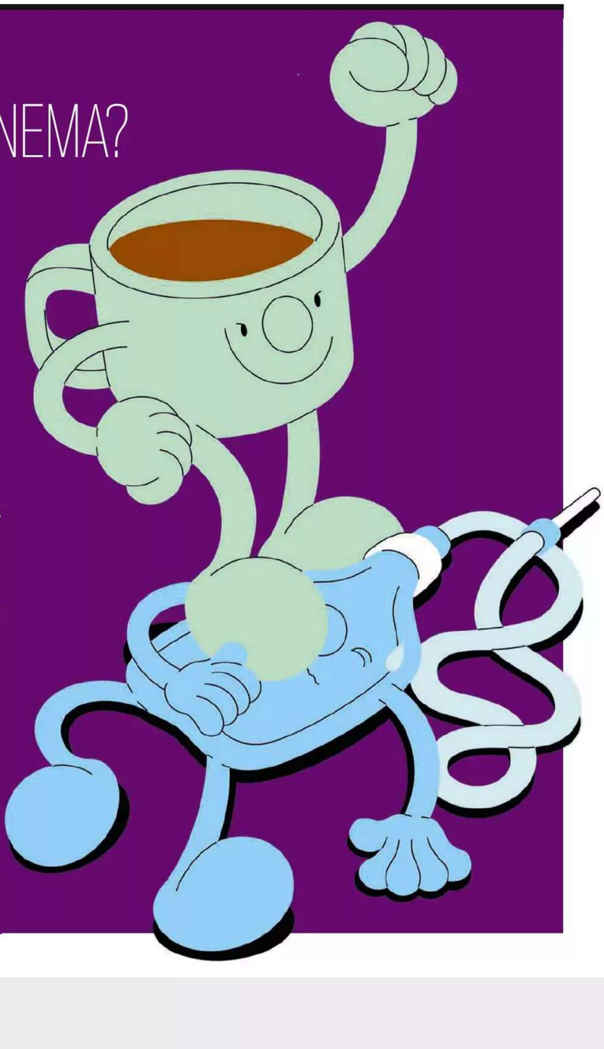
The concept isn't new: coffee enemas were part of the now-debunked Gerson therapy, a 1950s diet-and-enema based cancer treatment. Despite the TikTok revival, there's no good evidence that it works, but we do have plenty of reports of some unpleasant and potentially harmful side effects.

For one, your rectum isn't designed to handle coffee. The caffeine and acids can irritate the delicate tissue, leading to inflammation, pain and even burns if the coffee isn't cool enough. Over time, repeated enemas could damage the mucosal lining, increasing the risk of chronic problems. And while the trend promises "detoxification," your liver and kidneys are already well-designed to clear out toxins, so you don't need to try something so risky yourself.

Then there's the DIY risk factor. By doing something so invasive, you're inviting infections or even injuries such as rectal tears. Serious infections could lead to sepsis and even be life-threatening.

So, if you're looking to feel lighter or healthier, stick to the basics: eat more fibre, drink water and move your body. And if digestion's a struggle, chat with a healthcare professional, not an influencer.

Despite its newfound popularity, there's no reliable evidence supporting coffee enema benefits, and the risks are far from trivial. The 'bottom' line? Keep your coffee in your mug, not in your colon. ***NM***



be hard to find. Focusing on a period between 400 million and 4 million years ago, the researchers pondered what evidence might be left behind by this hypothetical society.

In just a few hundred years, our industries have made a huge impact on the world's climate and ecosystems. But if the human race vanished, within a few hundred million years, any direct evidence of our society – or a previous one like it – would almost certainly be gone. Our biggest cities would disappear in a geological blink of an eye, due to erosion and tectonic movements.

Instead, scientists searching for a long-lost civilisation would need to look for the geological fingerprints of their activities. Industrialised civilisation would likely have many of the same needs as modern humans, including producing large amounts of energy and food. So, we might expect them to leave similar markers in Earth's rocks and sediments, such as evidence of massive carbon emissions, global climatic changes and sea-level rise.

The problem is that in the geological record, climate change caused by a fossil-fuel burning civilisation is hard to distinguish from climate change caused by natural forces. In fact, there's an eerie similarity between modern climate change and events in Earth's history known as 'hyperthermals'. One such event occurred around 55 million years ago, when global temperatures rose by up to 8°C (14.4°F), but hyperthermals tend to coincide with intense tectonic activity.

> **"THE LONGER AN ADVANCED CIVILISATION LASTS, THE MORE EVIDENCE IT'LL LEAVE BEHIND"**

Another problem: the longer an advanced civilisation lasts, the more evidence it'll leave behind. But to survive a long time, a civilisation would need to become sustainable, which would leave less of a geological mark. A society powered by wind and solar energy, for example, wouldn't leave as much evidence as a fossil-fuel powered one. This paradox explains why we would be unlikely to find any signs of a past civilisation, if one existed.

The Silurian hypothesis pushes us to consider what traces of evidence humanity will leave behind. Answering these questions might help refine our search for advanced civilisations on other planets. ***CA***

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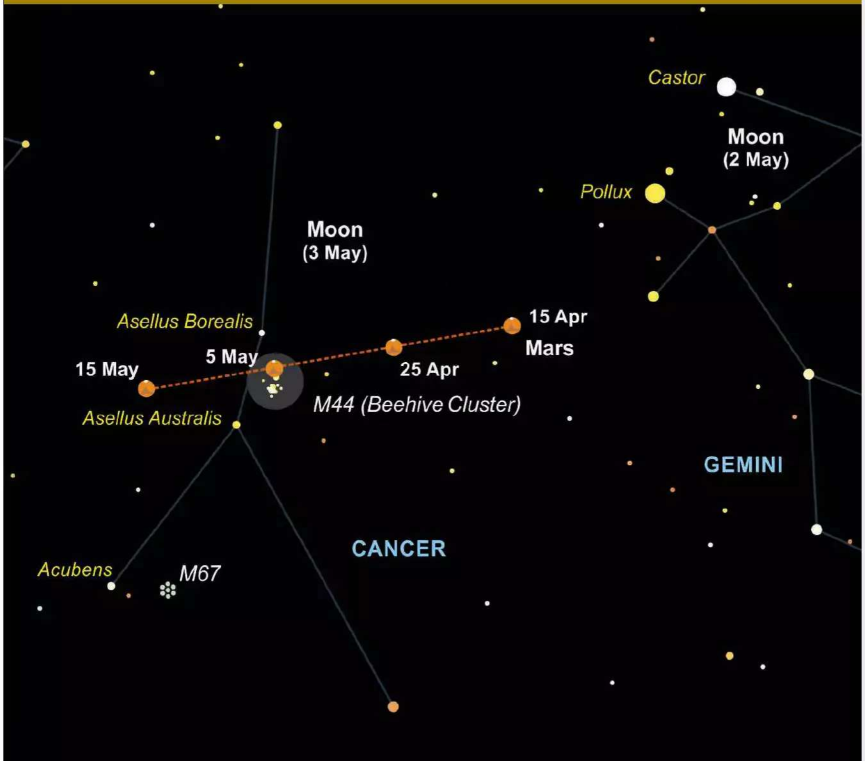
ASTRONOMY FOR BEGINNERS



HOW TO SEE MARS AND THE BEEHIVE CLUSTER

WHEN: APRIL TO MAY

Mars has graced our evening sky for a while, an orange-hued planet moving slowly east against the background stars. In the middle of April, it crosses the invisible border between Gemini the Twins, and Cancer the Crab. Gemini's main stars are Castor and Pollux. They mark the heads of the twins and you can find them by using the Plough, or Saucepan. Extend the line from the first star in the handle away from the pan, through where the handle joins the pan, extending for twice the length of the Saucepan to arrive at Castor and Pollux.

Cancer is a trickier pattern to find, but resembles a faint upside down 'Y'. At the heart of the 'Y' is a beautiful star cluster known as the Beehive Cluster, M44. It's visible to the naked eye, but binoculars offer a better sight, with the cluster stars nicely contained in the centre of the field of view. If you're not sure where to look to see the Beehive, Mars guides the way.

Mars continues to track east throughout April, getting ever closer to the Beehive at the start of May. On the evening of 3 May, Mars sits immediately northwest of the cluster's centre, moving north of the centre on the following night, 4 May.

If you're not sure which orange dot in the sky is Mars, there's another way to find it. Assuming it's clear on the night of 3 May, the waxing crescent Moon will sit just to the northwest of Mars. Drawing a line from its centre through to Mars will point directly into the heart of the Beehive Cluster at 11pm BST. The Beehive Cluster is also known as Praesepe, the Latin word for 'manger'. It sits in a box pattern and the two stars that form the eastern side of the box are known as *Asellus Borealis* and *Asellus Australis*, meaning 'northern donkey' and 'southern donkey' respectively. ***PL***

by PETE LAWRENCE
(@Avertedvision)
Pete is an astronomy expert and presenter on The Sky at Night.

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MADISON HALLADAY, VIA EMAIL

WHAT MAKES TARDIGRADES SO INDESTRUCTIBLE?

Tardigrades, also known among their many fans as 'water bears' or 'moss piglets', are quite possibly the cutest microscopic creatures on the planet – and off it. These mini-beasts have been sent up for a stint on the International Space Station and scientists have even launched them out into the vacuum of space. Left for days with no air, water or protection from intense solar radiation, the tardigrades, amazingly, did just fine.

Scientists are figuring out what makes these little animals so indestructible. When the going gets tough, tardigrades enter an extreme form of hibernation, known as cryptobiosis, in which they dry out and hit pause on their metabolism. Then, when conditions improve and water is available, the tardigrades will rehydrate and go about their business as if nothing happened.

In recent years, many pieces of the tardigrade puzzle have been falling into place. We now know, for instance, that a protein known as 'Dsup' moulds to their DNA and shields it from radiation, like a molecular suit of armour.

Researchers based at the University of Stuttgart have found evidence supporting the so-called 'Sleeping Beauty' hypothesis. The idea is that, in their resting state, tardigrades might not only pause their metabolism, but also their biological clocks. Water bears that had been periodically frozen lived twice as long, in their waking state, as a control group that never went to sleep.

In their natural habitats, tardigrades may only be active for a few months in total, but they can spread their lives out over many decades, sleeping through inhospitable periods.

A 2024 study focused on a recently discovered species of tardigrade, *Hypsibius henanensis*, which provided another piece of the puzzle. The research team found a gene in this species that produces pigments known as betalains, that help neutralise the harmful effects of UV radiation. They also learned more about a protein that speeds up DNA repair. The next step will be to see if these proteins protect any of the 1,300 known species of tardigrade. ***HS***

JAMIL PIERCE, SURREY

WHAT ARE THE BEST AND WORST FOODS TO EAT ON OZEMPIC?

When taking Ozempic (semaglutide), a medication prescribed for managing type 2 diabetes and sometimes used for weight loss, there are no specific foods that are off-limits. But ultimately, to make the most of the weight loss and ensure you have a sustainable, healthy diet in the long term, the following suggestions might be useful:

THINGS TO INCREASE...

1. HIGH-FIBRE FOODS Fibre slows down digestion, which complements Ozempic's effect of slowing stomach emptying. This can help keep you fuller for longer and avoid spikes in blood sugar. High-fibre foods include vegetables (like leafy greens, carrots and broccoli), fruits (such as apples, berries and oranges) and whole grains like oats.

2. LEAN PROTEINS Protein can also help stabilise blood sugar. Include lean proteins like chicken, fish and plant-based proteins, such as lentils and tofu, in your meals.

3. HEALTHY FATS Fats, like those in avocados, nuts, seeds and olive oil provide sustained energy and help with blood sugar control without causing spikes.

4. LOW-GLYCEMIC FOODS Foods with a low glycemic index, such as sweet potatoes and non-starchy vegetables, can also help to avoid sudden blood sugar rises.

THINGS TO REDUCE...

1. SUGARY THINGS Candy, pastries, soda and other sugary foods cause blood sugar spikes and can contribute to nausea and other digestive issues, which are common side effects of Ozempic.

2. PROCESSED AND FRIED FOODS These are usually high in unhealthy fats, salt and preservatives. These can worsen nausea and may interfere with blood sugar control.

3. SPICY FOODS As Ozempic reduces stomach emptying, it can make you feel a bit nauseous. Fatty, greasy and spicy foods can also upset your stomach, and might make these side effects worse.

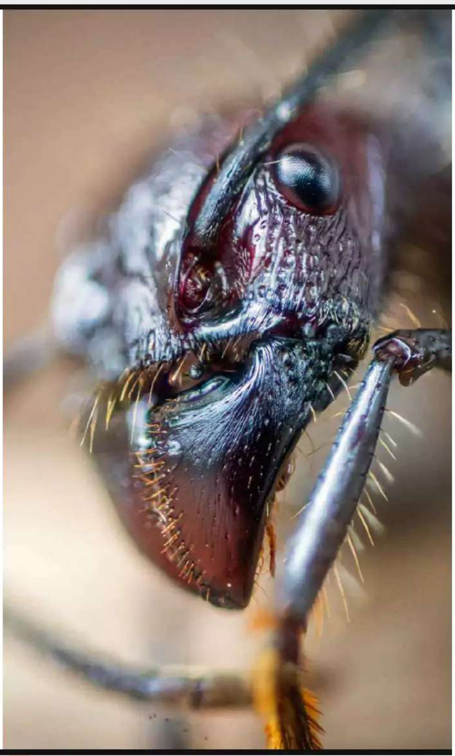
4. ALCOHOL Sometimes people find their alcohol tolerance has decreased when taking Ozempic, so it might be worth drinking more cautiously. In any case, alcohol has a fair few calories, which won't be helpful to overall weight loss. ***NM***

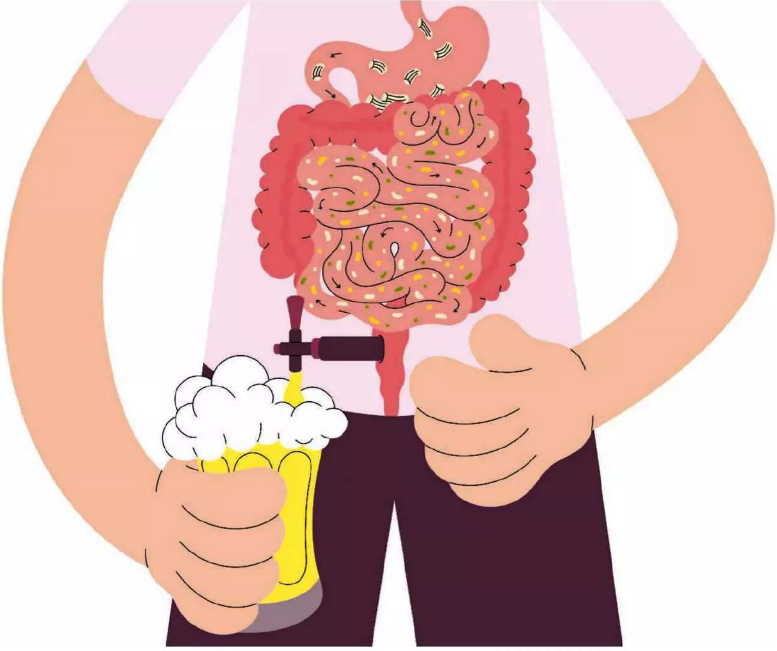
SAMUEL BECK, VIA EMAIL

WHAT'S THE MOST PAINFUL INSECT STING?

The Schmidt Pain Scale for Stinging Insects ranks the pain of insect stings on a scale of one to four. On this scale, the sting of the Western honeybee scores a paltry two, while that of the red paper wasp and Klug's velvet ant achieve a three. At four, however, is the sting of the South American bullet ant.

Entomologist Dr Justin O Schmidt, who won a 2015 Ig Nobel Prize for devising the scale, described being stung by the feisty nipper as "pure, intense, brilliant pain… like walking over flaming charcoal with a three-inch nail embedded in your heel." ***HP***





NATALIE MCGRATH, BIRMINGHAM

COULD I BREW ALCOHOL IN MY BODY?

Yes, but only if you have a very rare condition called auto-brewery syndrome (ABS), which occurs when certain bacteria and yeasts in the gut break down carbohydrates into ethanol. People with ABS can appear drunk, despite not having touched an alcoholic drink.

The most common microorganisms involved in ABS are the yeast species *Saccharomyces cerevisiae* and *Candida albicans*. Antibiotic use can set the scene for the syndrome by disturbing the gut ecosystem and allowing ethanol-producing organisms to proliferate. A diet rich in carbohydrates will exacerbate ABS, which is also more common in people with diabetes, Crohn's disease or liver cirrhosis. ***ED***

GETTY IMAGES X2, SCIENCE PHOTO LIBRARY ILLUSTRATION: JESS LEE

QUESTION OF THE MONTH

BEN DUSSAN, VIA EMAIL

WHICH ANIMAL HAS THE SHARPEST TEETH?

Shout out to the extinct 'chainsaw shark' (*Helicoprion*) which receives an honourable mention, because it had, what looks like a circular saw jutting out from its bottom jaw.

Terrifying? Yes, but its gnashers were not as piercing as that of another group of extinct beasts, known as the conodonts. Living from around 500 million to 200 million years ago, the mouths of these soft-bodied, eel-like creatures contained tiny, mineralised tooth-like structures called 'elements.'

With tips just two micrometres across – 1/20th the width of a human hair – not only were conodonts one of the earliest vertebrates to evolve teeth, they're also the sharpest dental structures ever to be measured. ***HP***

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WRITE IN

The writer of next issue's Question of the Month receives **two hardback popular science books**: *Nature's Memory* and *1,001 Days* **worth over £40!**

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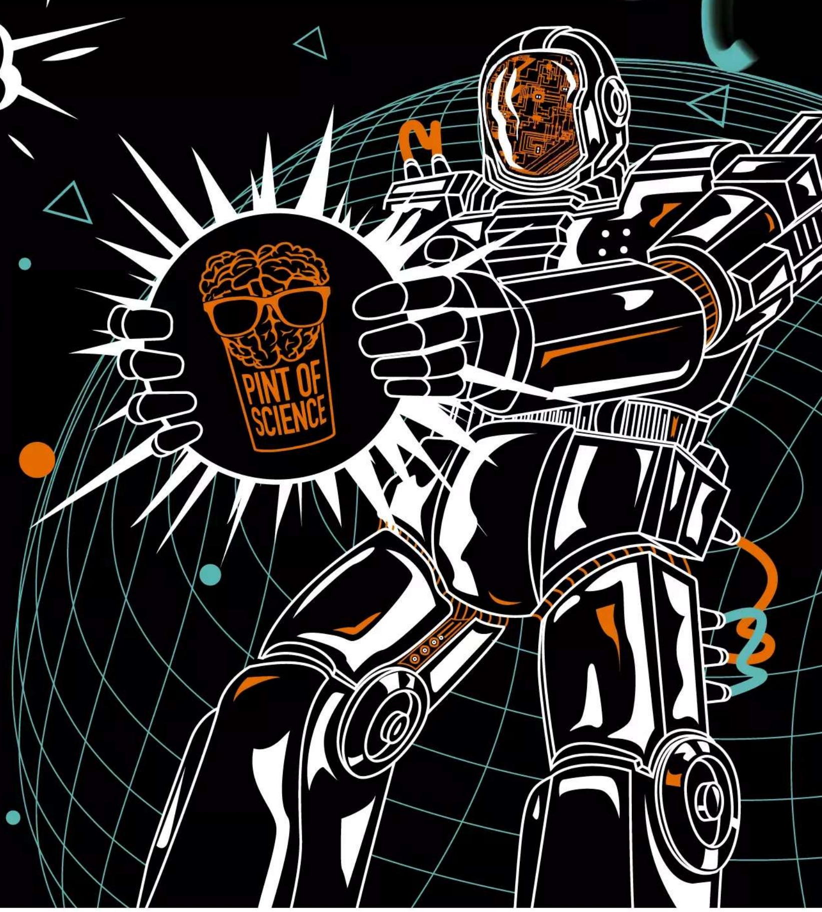
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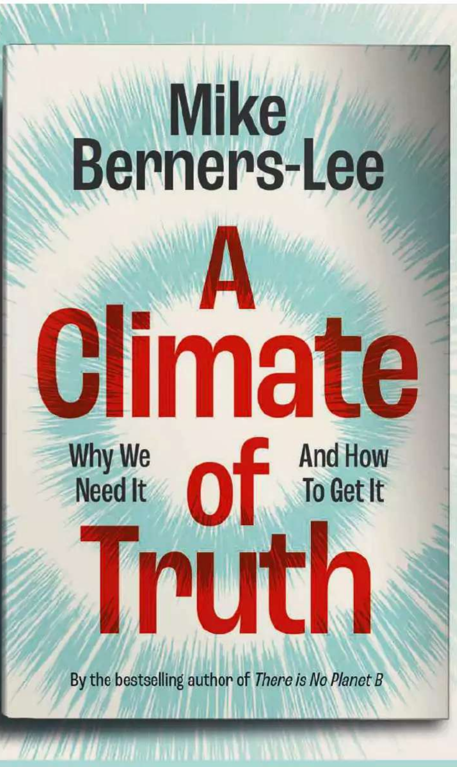
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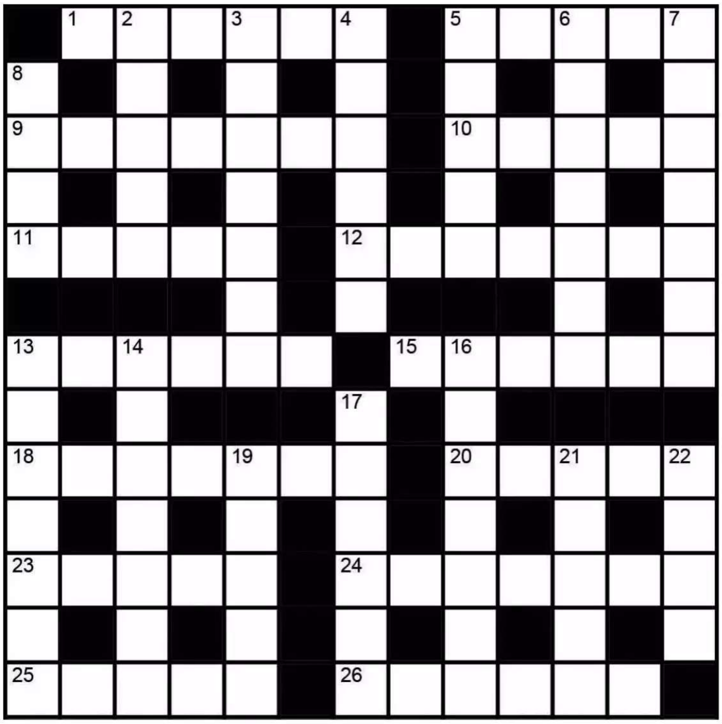


ACROSS

- **1** Worried assistance will follow, far off (6)
- **5** Terribly bored, but dressed (5)
- **9** A Catholic curse about the plaintiff (7)
- **10** Staring at a torn page (5)
- **11** Commiserated about skinflint (5)
- **12** Old barrier starts to get vandalised (7)
- **13** Assessing a sailor (6)
- **15** Frank also seen among detectives (6)
- **18** Mislay award outside, getting shot (5-2)
- **20** Line in a letter read out (5)
- **23** Organised tour around key royal house (5)
- **24** Revising and changing gin diet (7)
- **25** Huge order for lager (5)
- **26** Unexpectedly asleep, if you don't mind (6)

DOWN

- **2** Concentrate on what a camera can do (5)
- **3** Loser managed as well (4-3)
- **4** Ridicule notes on journey (6)
- **5** More almonds surround field (5)
- **6** Bishop, in tatters, boasted (7)
- **7** Right late coming round, journalist is feared (7)
- **8** Serene local man hides (4)
- **13** Article about concert (7)
- **14** Excessively red, moving right as required (2,5)
- **16** Get a key and some paper (7)
- **17** At university, retain service (6)
- **19** Eastern lake is strange and frightening (5)
- **21** Times changing releases (5)
- **22** Exaggerated gestures around the side (4)

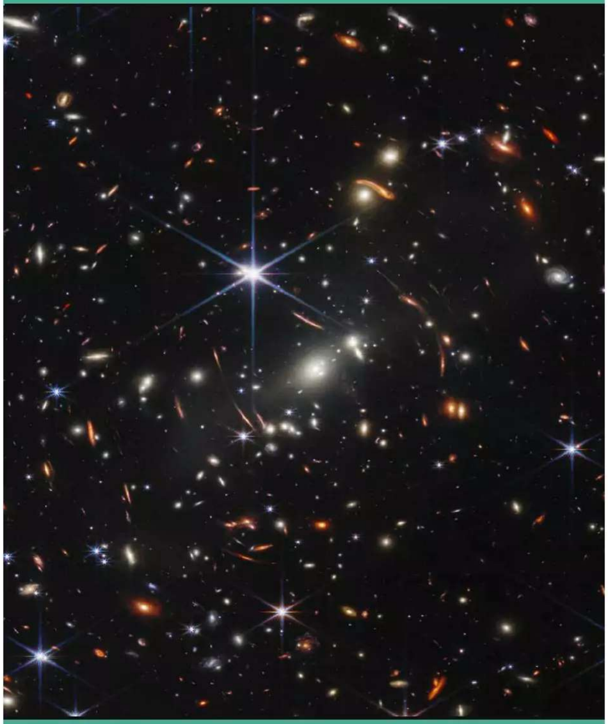
ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

NEXT ISSUE

TOO BIG, TOO SOON

The 'Universe-breaker' galaxies that are challenging our understanding of the cosmos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PLUS

MYCELIUM MINDS

Fungi are intelligent. So intelligent that some scientists think they could be conscious

SWEAT IT OUT

Is hard exercise the hangover cure we've all been missing?

ON SALE 13 MAY

BETTER LIVING THROUGH SCIENCE

A VOLUME CONTROL FOR YOUR APPETITE

Can we turn down 'food noise' to make healthy eating easier?

by **IAN TAYLOR**

Ian is a freelance science writer and the former deputy editor of BBC Science Focus.

Of all the myriad mysteries of science, the one that's currently got my neurons in a twist concerns a Toffee Crisp stashed away in my kitchen cupboard. I'm entirely preoccupied by it – it's like being pulled by some metaphysical tide.

The question is, how? How can a chocolate bar scrape away at my willpower when – the last time I checked – I was a halfway-intelligent adult who should know better?

The answer may have something to do with 'food noise': those persistent, intrusive thoughts about food and eating between mealtimes. In the case of my bewitching Toffee Crisp, these thoughts are probably a short-lived distraction that I'll give in to within the hour.

For some people, however, food noise is a more serious problem, that's according to Daisuke Hayashi, a doctoral researcher at Pennsylvania State University. He says that when the volume is dialled up, food noise is a feed of "constant and obsessive thoughts that detract from a person's wellbeing and make it difficult for them to make healthy choices."

Very little research has been done on food noise, but in 2023, Hayashi and his colleagues authored a paper that tried to marry anecdotal accounts of food noise with what we already know about how humans respond to food cues. His team is now working on a number of studies to delve into it further.

"RESPONDING TO THESE CUES IS WHAT KEEPS US NOURISHED, BUT SOME PEOPLE'S RESPONSES ARE HEIGHTENED"

"I'd say the research on food noise is at a stage where asking the right questions and seeking empirical data is more important than making confident assumptions," Hayashi points out. "One thing I can tell you from our preliminary data is that the majority of reports on social media describe food noise as a source of suffering and something people would rather live without."

Hayashi believes food noise occurs as a constant and intense response to food cues – anything from an ad on social media, to the smell of somebody's cooking, to the internal processes that control our appetite-regulating hormones. Responding to those cues is what keeps us nourished, but some people's responses are heightened.

"It's likely that a combination of individual characteristics – genetics, lifestyle, stress – and environments that are specifically designed to constantly expose us to powerful external food cues is what leads to someone experiencing food noise."

One interesting line of research comes from work on GLP-1 agonists, the class of weight-loss drugs that includes Ozempic.

"Anecdotal reports seem to indicate many people use the term 'food noise' to describe their obsessive thought patterns around food before receiving such treatments," Hayashi says. "My hypothesis is that one of the effects of these drugs, which might explain their effectiveness in treating obesity, is that they make people less responsive to food cues, thus making them less susceptible to food noise."

More research will answer that question, as well as others such as which people are most susceptible to food noise.

In the meantime, if you're looking for strategies to deal with intrusive thoughts about food (or rogue Toffee Crisp cravings), Hayashi recommends speaking with a dietician. They can help you look for patterns in your eating and plan strategies to build resilience against food cues. These may include things like slow, mindful eating or eating more at mealtimes to avoid hunger pangs between meals.

More importantly, Hayashi says, you have to avoid the guilt trap of thinking that struggles with food are some kind of personal failing.

"We're living in a paradoxical society where our culture constantly bombards us with messages glorifying thinness and muscularity, while also presenting us with non-stop exposure to external food cues that persuade us to make poor dietary choices," he says. "That – combined with social structures that make accessing healthy foods more difficult than eating convenient, highly processed foods of low nutritional value – is a perfect formula for struggling with food noise." **SF**

ILLUSTRATION: ROSIE ROCHE

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